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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

TRANSACTIONS FOR 1870.

PLACE OF MEETING,
THE SOCIETY'S HALL, WESTMINSTER PALACE HOTEL.

OFFICES: No. 6, WESTMINSTER CHAMBERS, VICTORIA STREET, WESTMINSTER.

LONDON:
E. & F. N. SPON, 48, CHARING CROSS.
NEW YORK:
446, BROOME STREET.
1872.

PREMIUMS FOR 1870.

At a Meeting of the Society, held on February 6th, 1871, Premiums of Books were awarded to:—

E. S. Crompton, for his Paper "On the Economics of Railway Maintenance."

Michael Sefi, for his Paper "On the Theory of Screw Propulsion."

W. Lloyd Wise, for his Paper "On the Patent Laws."

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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

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PLACE OF MEETING:

SOCIETY'S HALL, WESTMINSTER PALACE HOTEL.

OFFICES:

6, WESTMINSTER CHAMBERS, VICTORIA STREET, S.W.

1871.

TRANSACTIONS, &c.

February 7th, 1870.

INAUGURAL ADDRESS.

By WILLIAM ADAMS, President.

In taking the chair this evening for the first time as President of the Society of Engineers, permit me, before adverting to any other topics, to acknowledge the honour you have been pleased to confer upon me in placing me in my present position at the head of our Society. I have always deemed the election to the presidential chair to be a very great privilege, and considered that a large degree of responsibility rested with those upon whom it devolved to fill that office. Now that it has fallen to my lot to occupy the position, I can fully realize both the privileges to which I have succeeded, and the responsibilities by which I am surrounded. I am placed here under somewhat exceptional circumstances, having been elected under conditions which have not attended the election of any former President. Previously to our last annual general meeting it had been customary for the members of the Council to elect the President from among themselves. Owing, however, to recent modifications in the working details of our Society it is now the rule that the President shall be elected by the entire body of members and associates. This principle having been first carried out in my own case, I stand before you in the gratifying position of being the first President elected by the united suffrages of the whole Society. Judge then if I have not more than ordinary reason to rejoice in occupying the position in which you have so kindly placed me, and pardon me if I own to some degree of pride in the circumstance. Although I feel that the privileges of the position are enhanced by the special conditions under which my election has occurred, I cannot fail to perceive that the responsibilities of the office are also proportionately increased. To my mind, however, these responsibilities confer an additional privilege upon any member who

may have to bear them, when he knows that he may count upon the support, not only of his coadjutors in office, but of all his fellow-members, so long as he proves himself worthy to receive it. The ready support which the executive have always received at the hands of the members, and the cordial sympathy that has ever been shown towards your Presidents in all matters relating to the welfare and management of the Society, enable me, without presumption, to indulge in the belief that I may count upon that support and those sympathies being extended to myself. I am fully aware that I may, with the best intentions, be found to have many shortcomings, but I enter upon my year of office with an earnest desire conscientiously to merit the trust reposed in me, and with a sincere wish faithfully to discharge the duties of my office by devoting myself, as far as I possibly can, to the promotion of the welfare of our Society, in which I feel a genuine interest.

Passing on to subjects of more general interest I will, in the first place, refer to the Society itself. From its origin in 1854 down to the present time it has had a considerable degree of success, and although the last few years have seen a serious depression in commercial circles, which has naturally affected engineering matters, still the Society has made steady progress. What the results might have been had those years proved more prosperous for the profession no one can say. We should doubtless have made a very great advance, and have been stronger in every respect than we are now. Considering, however, the inactive condition of the times, we have no very serious cause for complaint. We now number nearly 500 members and associates, and are constantly receiving fresh accessions to our list. During the past year we have elected 29 new members—a number smaller than that of some of the preceding years, but which is accounted for by the depression under which the profession has laboured. From the balance sheet which has just been read to the Meeting, you will have learned our financial position, which, although not on the whole unsatisfactory, would be much improved by the payment of subscriptions in arrear. I wish to draw special attention to this point, and to ask you to aid the Council in their endeavours to maintain the Society on a sound basis by bearing in mind that its success depends, to a considerable extent, upon the subscriptions being promptly paid. This is one of the means by which the Society is sustained and materially developed.

Another important element of success is the reading and discussion of papers. And here a very wide sphere of usefulness opens out before us, inasmuch as the science and practice of ering are divided into numerous branches, and embrace

the knowledge and consideration of a great many subjects. We are fortunate in having in our Society gentlemen in every branch of the profession, to whom I would appeal to support the Society by preparing papers on subjects connected with their professional pursuits. A paper, to be valuable, needs not to be a very long one, although at the same time elaborate and comprehensive papers on subjects of interest are always appreciated. A short practical paper, however, is much more easily prepared, and often leads to a very important discussion. Without intending to detract from the merits of our papers, I am of opinion that our discussions are often most valuable, as they elicit the varied ideas and views of practical men upon the particular subject of the paper. In effect they add an additional value to the paper, for no paper is so useful to the Society as that which evokes a good discussion. By all means, then, let me urge upon each of you the paramount importance of adding something to the Society's Transactions by preparing a paper, no matter how short, no matter how simple, so that it is practical. Should any stimulus be needed beyond that great incentive to action which I conceive to have a place in the mind of every member —the Society's welfare—I would point to those silent tokens of merit now before you. I allude to the premiums of books which have this evening been presented to those gentlemen whose papers were selected for that distinction from those read during last year.

Besides the reading and discussion of papers there are yet other valuable sources from whence we, individually and collectively, obtain great benefit. These are the visits of inspection to the various works of importance in and around London, which are made by the Society during the vacation. No more practical plan could be devised for obtaining information than this, which in many cases enables the members and associates to examine works that would otherwise be inaccessible to many of them. During the past year we have had the opportunity of inspecting several works of very great importance connected with engineering. For this purpose we have received every facility from the Government, from public bodies, and from private firms, whilst the heads of departments and those in charge of works have invariably shown every courtesy in explaining details and in giving us the benefit of their experience in connection with the matters under inspection. In some cases the works visited have been in charge of members of our Society, and the manner in which they have striven to promote our interests upon every occasion of the kind are alike worthy of praise, of acknowledgment, and of emulation. Let us continue, then, to support the Society by our constant attendance on the

occasion of these visits, for a great deal is to be gained by so doing; a very great deal is lost by being absent. Not only do they open up new ideas to the mind, and add to our stock of information, but the general feelings evoked by a companionship unrestrained by the reserve incident to the proceedings of our ordinary meetings often lead to mutual advantages and to the formation of real and enduring friendships. Such, then, are the most prominent means offered for maintaining the status of the Society. Let us one and all use our best endeavours to further the objects in view by taking an active part in each of these matters.

Having referred in general terms to the papers read before the Society during the past year, I will now proceed briefly to notice them individually, pointing out the information they have brought us, and in some cases supplementing my observations upon them by statements of facts having a bearing upon the several subjects of which they treat. The first paper of the session was that by Mr. Perry F. Nursey, on explosive compounds for engineering purposes. The purport of the paper was to point out the various attempts that have been made to supersede gunpowder for blasting and similar purposes. The author showed that a great many compounds had been tried from time to time, but very few had been found to answer even moderately well, whilst fewer still had found their way into practice, those which had, being used to a limited extent only. Amongst the latter were gun-cotton and nitro-glycerine. We find that gun-cotton has been greatly improved by Professor Abel, who, by pulping the material and afterwards compressing it in solid cylinders, brings the dangerous elements completely under control. These cylindrical blocks burn harmlessly when lighted in the open air in the ordinary manner, but when fired in a close chamber their full power is developed. This principle of thus combining safety with force in a highly condensed form is a valuable feature in this material. We also find that the resistless energy it contains is developed even in the open air r firing the cylinders with a detonating fuse. This feature is luable in a military point of view. With regard to nitro-ycerine, it is to be deplored that the use of such a fearfully ngerous compound should be allowed. Serious accidents nave happened with this substance both at home and abroad. Since Mr. Nursey read his paper we have had a sad accident and loss of life from the explosion of two cartloads of nitro-glycerine near Carnarvon. Still later, in fact only very recently, we have had the news of the explosion of 4000 lbs. of the same bstance sville, with the usual results of widespread ath a ion of property. It is certainly a matter of

wonder to me how people can be found to transport and use nitro-glycerine in its ordinary form, when it can be had in the form of dynamite, as pointed out in Mr. Nursey's paper. This dynamite is nitro-glycerine mixed with fine gravel, and which, when lighted with an ordinary fuse, simply burns quietly away. When, however, it is lighted with a detonating fuse its intensity of action becomes manifest. Nitro-glycerine in this new condition appears to be practically free from danger, and if such violent explosives are to be used, this would seem to be a very safe one. Between gun-cotton and dynamite it therefore now rests as to which shall supersede gunpowder for engineering purposes. Gun-cotton has the start at present, although there is no reason why dynamite should not find equal favour. It probably will when nitro-glycerine ceases to be used, and the prejudices its highly dangerous character has created against any compound into which it enters have been overcome.

The next paper was on the drainage and water supply to the town of Fareham, by Mr. Thomas Buckham. This paper is a striking comment upon the value and importance of the sanitary measures to the necessity of which the public have awakened during the last few years. Ten years ago the author tells us that the greater part of the houses were drained into cesspools, badly constructed in a gravel soil, and contiguous to the wells. Some houses were drained into open ditches, where they created pools of stagnant filth, in many cases close to the dwellings of the poorer classes. Since the year 1860 a system of pipe drainage from, and water supply to, every house in Fareham, in connection with a well-designed arrangement of sewers and water mains, has been effected. Mr. Buckham's paper gives the details of all these arrangements, which will be found useful to those having similar works in hand, as a practical example of successful work in sanitary engineering. Such pictures as the town of Fareham formerly presented are, I am happy to say, becoming more and more rare every year, although there is much good work for the sanitary engineer which must be accomplished before our standard of health can be raised generally to the pitch we know it to be capable of attaining. The progress of sanitary engineering as regards the utilization of sewage during the past year has not been very marked. Existing sewage farms have been efficiently maintained, although I am not aware that their limited number has been added to. A good example, however, has been set by Mr. Hope, of the Lodge Farm, Barking, who has taken a farm of 350 acres, upon which he intends utilizing the sewage of one of the country towns in Essex. The subject of sanitary legislation made little or no advance last year, although a great deal of investigation and

discussion took place upon the subject. The town of Barking has given some trouble, and its condition demonstrates the necessity of sound and immediate legislation. Compulsory measures are unquestionably necessary in this direction; it should either be obligatory upon the inhabitants of towns to effect the required improvements, or, in their default, the State should be enabled to step in and adopt the necessary measures.

The science and practice of electric telegraphy found an able exponent in Mr. E. G. Bartholomew, who favoured us with a paper on that subject, and which he treated irrespectively of telegraphic apparatus. This interesting paper, to which a premium has been awarded by the Council, brings before us a large amount of practical information upon the subject of telegraphy as applied to land lines, and also to submarine lines. Mr. Bartholomew points out that it is mechanical knowledge which assists us most in the construction of a land line, whereas the manufacture and submergence of a telegraphic cable involves, besides that in a much higher degree, an acquaintance with many chemical facts and a knowledge of the laws by which electricity is governed, to a much greater extent than is necessitated by the former case. We are then informed upon the special details relating to the manufacture and laying of these two classes of lines as well as upon those relating to subterranean lines. The paper will be found of value to those who are seeking information upon the subject; and now that electric telegraphy is making such rapid advances all over the world, its value would be greatly enhanced if the author would kindly supplement it by a paper on that portion of the subject not yet treated of—telegraphic apparatus. I am aware that it opens up a very wide subject, but the author of the paper under consideration has proved himself capable of dealing with the matter in a concise and practical manner, which, for the purposes of the Society, would be found more valuable than an elaborate and exhaustive treatise.

Having referred to the great progress that has lately been made in electrical communication with foreign parts, and which has been stimulated by the success of the Atlantic cables, I may here offer a few remarks on that head as well as upon the prospects of the year before us as regards telegraphy. Foremost amongst the many events of the past year at home stands the transfer of the Electric Telegraphs to the Post Office. Although many delays occurred to retard the actual transfer, still most of the staff arrangements were made, and sufficient was effected to enable us to class it with the accomplished facts of the year—an event by which it is hoped the public will be gainers. Next we have to record the successful laying of the

French Atlantic cable by the 'Great Eastern' and some smaller vessels. The total length of this cable is 3564 miles; it was laid in two sections from Brest to St. Pierre, and from the latter point to Duxbury, near Boston. The Persian Gulf cable, over 500 miles in length, was also laid, and completes the duplication of the Indo-European telegraph between Bushire and Kurrachee. The cable between Bornholm, in the Baltic, and Libau, on the Russian coast, and also the Tasmanian cable, were successfully laid during the past year. The Indo-European line, from Nordeney, in Prussia, to Teheran, in Persia, including 110 miles of submarine cable for the Black Sea, was completed; and the Cuba and Florida cable, partly submerged in 1868, was recovered, and communication established by means of this, a second cable, during the past year. Amongst works of this class of lesser extent I may mention the Malta and Sicily, 80 miles; the Norwegian, 53 miles; the Peterhead and Norway, 285 miles; the Orkney Isles; the Scilly Isles; and the Corfu and Santa Maura cables. As an indication of the work done in telegraphy during the past year, I may mention that the Telegraph Construction and Maintenance Company alone, and independently of other firms, manufactured 7000 miles of line, whilst the total manufacture in 1868 was but a little over 3000 miles.

But if we have had this activity prevailing in the past year in telegraphic matters, we have promise of still greater enterprise in the year before us, several large schemes having been matured and the work of manufacturing the cables commenced. We have just had completed the new Indo-European overland line from the North Sea to the capital of Persia. From thence a double line of telegraph already exists, which the Persian Gulf cable completed. This constitutes a second through route between England and India, and we may expect the completion of a third route in this direction in about another month. This will be formed by the submergence of the British-Indian Submarine Company's cable between Bombay, Aden, and Suez, in connection with the Anglo-Mediterranean Company's submarine line to Malta, and the land lines from Sicily, &c., to England. The Falmouth, Gibraltar, and Malta cable is now in course of manufacture, and when submerged will render the third Indian route entirely submarine. The other projects which have been matured are the British-Indian Extension Company, who will lay a submarine cable from the Indian system at Ceylon to Penang and Singapore. From that point the China Cable Company will lay a cable to Hong Kong and Shanghai. Then there is the Australian Company, which, in connection with those I have just named, will lay a cable from

Singapore to Java, and from thence to Darwin on the north-west coast of Australia. Considering the commercial and social importance of that country, the only wonder to me is how it has been neglected so long with respect to telegraphic communication. From the extensions above referred to, it requires no great spirit of divination to perceive that out of them must necessarily grow still further extensions. The China cable will doubtless be carried on to Pekin and the Japanese Islands, whilst from the Australian line we may expect a cable from Tasmania to New Zealand, Tasmania already being united to Australia by telegraph. The West India and Panama Telegraph Company will in the course of a few months establish communication from Cuba to Jamaica and Panama, and from Jamaica to Porto Rico, St. Thomas's, Barbadoes, Trinidad and Surinam in the South American continent. Besides the foregoing there are a number of other telegraph extensions spoken of as likely to be effected during the present year, one scheme being another Atlantic cable. This latter proposition, however, requires careful consideration, inasmuch as it would probably be better to employ capital in telegraphic lines for parts not yet electrically connected, rather than to expend it in what may prove fruitless opposition. It will thus be seen that telegraphy has a brilliant future before it. Backed as it is with the matured experience of the past, the submarine branch of the science is now no longer a matter of doubt and speculation, and in this department especially do we see signs of ample work for our telegraphic engineers.

The paper which followed Mr. Bartholomew's was one by Mr. C. M. Barker, on joints for the prevention of leakage in gas and water mains. The author describes the two systems of joints in ordinary use for gas pipes; one when the pipes are turned and bored, and the other when the joints are made tight with lead and the set hammer. Each of these methods has its advocates; each has also its defects; and a great loss of gas is annually experienced through leakage. The author proposes to remedy this state of things by a rigid joint which he has invented. His idea is that by having a perfectly rigid joint and strongly-made pipes, their tensile strength will enable them to bear more than any usual amount of displacement. The joint is ingeniously constructed, but whether it will be found to answer in practice remains for experience to show.

One of the most interesting papers of the session was that by Mr. F. W. Hartley upon the various methods employed in determining the commercial value and the purity of coal gas. Th[illegible], which has been awarded a premium, was illus-tr[illegible] umerous experiments, which doubtless afforded to

all present that evening the gratification experienced by myself. Mr. Hartley gave a clear and valuable exposition of the methods by which the purity and value of gas is determined, and his paper leads us to the conclusion that there is no other country besides England where gas is subjected to such rigid supervision and severe analysis. We are constantly hearing complaints about bad gas and the like; but were consumers to look to their burners and fittings, they would often find the fault to lie with them, and not with the much-traduced gas companies.

The preceding paper was appropriately followed by one on apparatus for burning coal gas, by Mr. W. Sugg, who also rendered his paper interesting by practical experiments. The object of the author was to show the relative economy and power of the various kinds of burners, and he clearly demonstrated that many burners in use were constructed on very faulty principles. He then stated what duty a really efficient burner ought to perform, and exhibited one of his own design, which appeared to fulfil all the necessary conditions of a good burner.

The first paper after the vacation was by Mr. Perry F. Nursey, upon a subject which has attracted considerable attention during the past year—that of international communication. Mr. Nursey gave a general outline of the history of the question of communication between England and France from early times. He then described at length the various schemes and proposals for connecting the two countries by tunnel, tube, ferry, and bridge, and including the plans of Hawkshaw, Bateman, Fowler, Boutet, and others. Mr. Nursey analyzes the various schemes, and points out both their merits and their defects. He arrives at the conclusion—with which I think the greater number of us here will coincide—that most of the proposed schemes are too gigantic in their nature for adoption at the present time, leaving the question of feasibility out of sight. Hence it will be far better, pending the somewhat remote realization of the more costly proposals, to spend some five or six hundred thousand pounds in improving the harbour accommodation on either shore, and to set afloat an improved build of vessels, rather than to continue the present miserably inefficient system of Channel transit in the hope of some day having a tunnel, a tube, or a bridge whereby to cross dryshod. For this paper Mr. Nursey has had a premium awarded to him, which is the fourth the Society have had the pleasure of presenting to him for papers read by him. Since the paper was read Parliamentary plans have been lodged for a scheme of intercommunication between Dover and the coast of France at a point not yet named. The plans involve some alterations in the present pier and harbour arrangements, to which I understand the

local authorities object. The latest reports that have come to hand upon this subject are that a deputation from an English company formed for the organization of a service of specially constructed steamboats between Dover and Audresselles have had an interview with the French authorities. Nothing definite, however, has transpired, except perhaps the expression of dissent on the part of the municipalities of Calais and Boulogne, who are strongly opposed to the scheme.

The necessity of further experiments on the strength of materials was shown in an able paper by Mr. C. J. Light, who pointed out the discrepancies between the various authorities upon the subject. Although a great deal has been done to clear the field of practice from many of the doubts and obscurities of theory which formerly surrounded and hampered it, there is still a wide range of opportunity for further perfecting our knowledge, owing to the varied applications of materials and to the changes which are constantly taking place in their manufacture. Still, I hold that for all ordinary purposes we have a sufficiently near approximation to the truth to prevent any engineer who knows anything at all of practice from going very far wrong. At the same time it is quite clear, as shown by Mr. Light, that it will not do to refer to many of the authorities, or we become lost in doubt and bewilderment—a sure sign that we require some settled standard.

The concluding paper of the year was by Mr. Vaughan Pendred, who described the various apparatus in use for measuring the speed of ships. He brought prominently before our notice the very simple and unique apparatus known as the Berthon log, and of which many amongst us possibly had no previous knowledge. Many interesting facts were contained in the paper, for which a premium has been awarded to the author, whilst others were elicited in the discussion which followed and in which the practical value of the Berthon log was fully demonstrated by Admiral Halsted, and others who had used it. I need not here dwell on the importance of such a simple and perfect apparatus for measuring the velocity of ships, nor need I insist upon its superiority over other forms of log, as the subject, having been so recently before us, must be fresh in most of our minds.

It will thus be seen that during the past year we have had nine papers read, four of which have been selected for having premiums awarded to their authors. Whilst these four stand out somewhat from the rest by reason of this distinctive recognition, it is not to be assumed that the remainder were without their own special merits. On the contrary, the warmest thanks of the Society are due and are given to every member or asso-

ciate who comes forward to aid and thus materially to promote its interests.

Turning from the subject of our papers I will next offer a few remarks upon several matters connected with that branch of the profession in which I am specially engaged, locomotive engineering and the rolling stock of railways. In locomotive construction the use of steel is steadily extending, competition having had the usual effect of reducing its price. Much valuable experience has been gained with regard to the properties which this material should possess when used for the working parts of machinery, and the fact is now fully recognized that its distinctive features should be moderate but uniform tensile strength, with great toughness, the chief aim of manufacturers of steel for constructive purposes being to keep down its tensile strength to a maximum of 35 tons per square inch. As a material for tyres, axles, horn blocks, and some other parts of locomotives, steel has now become an established success. Its most important use, however, is for wheel tyres, which are the parts of an engine most subject to wear. Good steel tyres have at least four times the durability of the best iron, and wear with extraordinary regularity on well-balanced wheels. Steel has not hitherto made so much way as a material for locomotive boilers as might have been expected, considering the rapid extension of its use for other purposes where iron was formerly employed. The great advantage that may be expected to accrue from its use is an addition of nearly 50 per cent. to the strength of our boilers with the same thickness of metal as is now used in iron, or in enabling us to reduce the weight to some extent. The high pressures to which locomotive boilers are now worked render it very desirable that they should be of the greatest possible strength. There is, however, a fear on the part of many engineers, which may be well grounded, that in adopting steel for boilers, some of the plates may prove to be brittle and cause disastrous failure. A longer experience of this material will doubtless inspire greater confidence in it, and the time is probably not far distant when steel will be exclusively used for first-class boilers. I consider the subject of steel to be one of the most important in connection with mechanical engineering, and deserving of very careful attention. The development of steel manufacture has already led to great results, but we have not yet effected all that may be accomplished with this material, which I believe to be destined to enter still more largely into use in engineering practice. My remarks on steel would, I think, be incomplete were I to omit here to mention how much the profession is indebted to men of enterprise and genius like Bessemer, Krupp, and others, for the great improvements

they have effected in the manufacture of that material. I may also refer to the labours of one of our members—Mr. Kirkaldy—whose valuable experiments have done so much to promote the introduction of steel into many departments of practice.

Among the improvements in the details of locomotive engines which are being attempted may be mentioned equilibrium slide valves, some of which seem likely to answer the purpose very well. There is no doubt it would be an advantage to relieve the valves and valve gear from the heavy pressure of the steam, but unless it can be accomplished by very simple mechanism it will be found unsuitable for locomotives.

Before quitting the subject of locomotive engineering, I wish to direct attention to the important invention of M. le Chatelier, for using steam as a brake in locomotives. M. le Chatelier's invention consists in reversing the engine and simultaneously admitting a mixture of steam and water to the cylinders, so as to prevent injury to the pistons and valves by the hot gases and dust from the smoke box. The apparatus is exceedingly simple, consisting of nothing more than a 1-inch tube, which communicates between the boiler and the exhaust pipe, and thence to the cylinders, and a distributing cock by which the driver regulates the supply. This counter-pressure steam brake came to us as a novelty during the past year, although it had been applied to nearly three thousand locomotives on the Continent. It is now being tried in England, and, so far as it has at present been used, it is favourably spoken of. As applied to a tender engine it gives additional brake power, the ordinary tender brake being also available.

Continuous brakes on carriages appear to be coming more into favour for fast trains. The most efficient brake that has come under my notice is that invented by Mr. John Clark. The retarding power in this brake is obtained from friction wheels attached to a chain drum, suspended under the framing of a brake van. By bringing the friction wheels into contact with the wheels of the brake van, when running, they are caused to revolve, and a chain connected to the drum and to the several brakes in the train is thus tightened and operates the brakes. Among the advantages claimed for this system of brake are its requiring very little exertion on the part of the guard to apply it, as the power is given out by the momentum of the train, and it has merely to be put into gear when required. It has a principle of self-adjustment which provides for unequal wear of the brake blocks, and the continuous chain which runs through the centre of the train is so arranged that it can be easily and quickly connected, not being in any way affected by turning the carriages round.

There have not been many novelties introduced into this country during the past year in connection with rolling stock, but some important questions having a bearing upon this subject have received considerable attention. Amongst other points may be mentioned the possible reduction of dead weight in proportion to paying load, and the better adaptation of engines and carriages to sharp curves and steep gradients. It does not appear that any practical scheme has yet been brought forward for remodelling and lightening our rolling stock, which would provide sufficiently for the exigencies and fluctuations of traffic, due regard being had to efficiency and economy of working, the comfort of passengers, and the necessary stability of vehicles for ensuring safety at high speeds. The long double-bogie carriages adopted in American practice have doubtless the merit of running with great steadiness on rough roads and round sharp curves. They are, however, unfitted in many respects for the traffic of this country, and their dead weight in proportion to carrying capacity is even greater than that of English carriages. With a view to a reduction of weight long carriages have been tried on several of our railways, variously fitted with four, six, and eight wheels. But they have not been found advantageous in the long run, having generally given place to carriages of moderate length. An instance of this may be found on one of our own railways, where, after several years' experience of carriages 40 feet in length, carried on eight wheels, twin carriages of half the length, and on four wheels, have been recently introduced. The subject of dead weight in rolling stock is admitted to be one of vital importance to the success of railways, and there is no doubt it will continue to receive the anxious consideration of engineers engaged in its construction and working.

Bearing very closely upon the foregoing questions are Mr. Fairlie's steam carriage and double-bogie locomotive engines. These engines appear to run very smoothly, and they take sharp curves with great facility. It is, however, quite a question for experience whether gain of adhesion will justify the great cost of these engines and the entire duplication of the working parts. This system is now in the way of a fair practical trial. The steam carriage has already been working on the Sevenoaks branch of the London, Chatham, and Dover Railway, some small double-bogie engines are working on the Festiniog Railway, and two more are about to be sent over to Sweden.

The year which has recently closed upon us stands distinguished by the completion of some important engineering works both at home and abroad. Looking at home, our thoughts instinctively wander in the first place to the magnificent new

bridge over the Thames at Blackfriars. I say our thoughts instinctively revert first to this structure, because it has grown into its present elegant form under the hand of our President for the past year, Mr. F. W. Bryant. I need scarcely here mention what has been a matter of observation to all of us, that both in the removal of the old bridge, and in the erection of the new one, many difficulties of a very special nature arose and were surmounted by Mr. Bryant, who acted as engineer to the contractors, Messrs. A. and P. Thorn, who are also members of our Society. I do not lose sight of the circumstance that the design of the new bridge is due to Messrs. Cubitt and Carr, whose work is one which possesses great merit, and is a striking improvement to our metropolis. Within sight of the elegant stone and iron structure which replaces Mr. Mylne's stone bridge stands another work worthy of our city. I refer to the viaduct which has been constructed over that dangerous spot known as the Holborn Valley, and which had too long been a disgrace to London. This work presents features of an interesting character, and includes improvements of roads and approaches over a large area contiguous to the line of the viaduct. It was an unfortunate circumstance that the beauty of the Farringdon-street bridge should have been marred by the cracking and splintering of its granite columns. It is satisfactory, however, to know that the utility of the structure remains unimpaired.

Returning in our retrospective review to the river, we find that the southern portion of the Thames Embankment, between Lambeth and Westminster, has been completed and opened to the public during the past year, whilst that portion of the northern embankment between the Temple and Blackfriars has been pushed on, and fast approaches completion. Proceeding still eastwards along the river, we next come to the Tower subway, which is being carried by Mr. Peter W. Barlow, jun., under the Thames from Tower-hill to Tooley-street. This work was to have been completed by the end of last year, but circumstances have arisen which have delayed its opening. Still farther east we find the Thames Tunnel shorn of all its ancient glory, and now appropriated and utilized by the East London Railway Company, whose line runs from Wapping, *viâ* Rotherhithe, to New Cross and the Old Kent Road. One of our summer visits was made to the works of this railway, which has since been opened for public traffic. The line will eventually be extended from Wapping to Liverpool-street, but this will occupy some time, as the works are exceptionally heavy.

Besides these public works, we have had two new parks opened during the past year, one in Finsbury and the other in Bermondsey. A portion of the new street from the Mansion

House has been opened, whilst Columbia Market affords a splendid instance of private munificence and taste, although, unfortunately, as a market, it has not as yet proved a success. The great scheme of the Chartered Gas Company is rapidly progressing on a piece of land near Barking Creek. Large blocks of industrial dwellings have sprung up in various parts of the metropolis, new streets have progressed, and the laying of tramways has been commenced. In the provinces we have the completion of the new Albert Dock at Hull, and the Wolf Rock Lighthouse at the Land's End.

Looking abroad, the mind naturally rests first upon the Suez Canal, which has been so successfully engineered by M. de Lesseps. This is one of the great achievements of the present age, and we may congratulate M. de Lesseps that the idea of connecting the Red Sea with the Mediterranean has been so successfully accomplished, cherished and promoted as it has been by him, through so many years. The accomplishment of this project has reopened the question of an inter-oceanic canal through the Isthmus of Darien. It may be remembered that early in the year 1868 we had a paper on this subject from Dr. Cullen, which was replete with valuable information. Such an important project is worthy of every consideration, and I am informed that a French company has recently taken some steps towards the practical solution of the question. The great railway across the American continent, and which exceeds in length the sea passage from Europe to America, is another of the engineering triumphs of the present century.

As I pursue my retrospective glance, events and circumstances crowd in upon my thoughts, but I fear time would fail—and your patience also—were I to enlarge further upon the present subject. Suffice it, then, to observe that many improvements have been effected in various departments of science and the useful arts, although no important or striking discovery or event has been chronicled.

With reference to the position of our profession generally during the past twelve months, it must be admitted that it has felt the effects of the commercial depression which has, more or less, for the last five years, influenced every department. But affairs appear to be changing in this respect, and the new year has opened with signs of returning animation. I hear on all sides of improving prospects, and of the development of practical schemes, which lead to the conclusion that better times are dawning upon us. In looking at the sources from whence we may expect work, Russia appears to be one of the most promising countries. A vast field is there open for enterprise, both with regard to mechanical and civil engineering, so that we may

anticipate a considerable amount of work from that quarter. There are other directions in which we may likewise look for employment for our profession, but Russia, if I mistake not, will prove a great field for engineering operations. At any rate, be that field where it may, the future prospects of the profession are very much more encouraging than they were a year ago, so that we commence the present year with renewed hope.

We meet here to-night for the first time in our new hall. We have exchanged the one where we have for so many years past held our meetings, for the present one, which is in the centre of the head-quarters of the profession. May we progress and prosper under the new roof as we did under the old one, and may the present gathering be an earnest of many yet to come in which we each may take part.

March 7th, 1870.

WILLIAM ADAMS, PRESIDENT, IN THE CHAIR.

FRICTION IN STEAM CYLINDERS.

By PETER JENSEN.

So few data exist on the subject of friction in steam cylinders that the author approaches it with some diffidence, more especially as he has not had time to make direct and comprehensive trials which would furnish particulars for exhaustive treatment of the subject. He, therefore, can only offer such remarks and make such deductions from the experience of others and of himself as have a bearing on the subject, without assuming to settle questions relating thereto. Of the importance of the subject there can be no question, as engineers are aware of the great percentage of power that may be consumed in piston friction. Hence it is well to define this loss under various circumstances, and then to apply remedies for diminishing the loss. Friction in the steam cylinder may be classed under three heads: piston friction, slide valve friction, and stuffing box friction. As regards piston friction, it ought to depend upon the working pressure, the packing material employed for keeping the piston tight, the extent of the rubbing surface of the packing, and the means of lubrication. It is evident that a piston should not be made to stand a higher pressure than that it is intended to work with, otherwise a great amount of power may be lost by unnecessary friction, and wear and tear both of piston and cylinder will ensue. It also appears evident that engines expanding the steam to any great extent in one cylinder should have piston packing, the tension of which is dependent upon and constantly varying with the pressure of the steam at any part of the stroke. There is not, it is believed, any difficulty in this, and all are doubtless familiar with one or more constructions of pistons of this sort which answer the purpose in a greater or less degree.

The common rough and ready way of calculating piston friction by assuming a certain constant pressure per square inch of piston as being the measure for the piston friction (which, as will be seen presently, constitutes by far the greater

portion of the total friction) of the engine itself is erroneous, or at any rate should be used with discrimination. Although it has been found in a few instances that the friction of the piston, for instance, in an engine working with $2\frac{1}{2}$ atmospheres may be expressed by (say) 2 lbs. per square inch of the piston, which may or may not mean that the piston packing has had just the requisite amount of tension, and not perhaps 50 per cent. more than requisite, we have no right to infer that the same rule holds good with 5 or 10 atmospheres pressure. If the piston packing has just the right tension, the friction must amount to a certain percentage of the pressure. But we must not lose sight of another circumstance, namely, that the circumference of a piston increases as the diameter simply, while the area increases as the square of the diameter.

The question is, has a piston of 24 in. diameter double the amount of friction, or has it four times the amount of that of a 12-in. piston, other circumstances being alike, that is, with the same material, same depth of packing, state of lubrication, pressure, &c.? We must not forget either that the proportionate depth of packing varies with the diameter of the cylinder. Whether it is supposed to give less wear on the piston rings (an opinion considered incorrect by the author) or not, we need not stop to discuss; the practice is, however, not to increase the depth in direct proportion as the diameter of the piston increases in size, and thus it is that the piston friction does not in practice decrease in the ratio otherwise anticipated, though it is believed that it does decrease. In other words, it is propounded that piston friction as percentage of power decreases as diameter increases, but increases as pressure and depth of packing increase, the packing material being the same. In practice the following rule holds good:—Depth of packing $= \frac{3}{4}\sqrt{d}$ in inches: for instance, for a 19-in. cylinder, depth of packing $= \frac{3}{4} \times 7 = 5\frac{1}{4}$; for smaller engines, $\frac{2}{3}\sqrt{d}$ (say) 16-in. cylinder, depth of packing $= \frac{2}{3} \times 4 = 2\frac{2}{3}$ in. This is for cast-iron packing rings. With Ramsbottom's steel rings a much smaller depth is found quite sufficient. Hence if it is found that 2 lbs. per square inch is the measure of the piston friction in a 12-in. cylinder, it would seem that the friction of a 24-in. cylinder (having four times the area but only double the diameter) would only be double, but as the depth of packing is as $2 \cdot 3$ to $3 \cdot 89$ it would become $\frac{3 \cdot 89}{2 \cdot 3} \times 2 = 3 \cdot 38$, so that the pressure per square inch absorbed by piston friction would become $2 \times \frac{3 \cdot 38}{4} = 1 \cdot 69$ lb. per square inch in a 24-in. cylinder, and

2 lbs. in a 16-in. This is of course assuming the ordinary theory of piston friction to be correct, namely, that it is to be calculated by the superficial area of the piston packing × the pressure of the steam × the friction coefficient. If, then, the above be correct it is clear that we must avoid taking a certain fixed percentage of the pressure on the piston area as the measure of the piston friction, except we take the size of the cylinder into account.

The packing material has considerable influence on the friction. Hemp packing for moderate and for high pressure causes more friction than metallic packing, which is now almost universally adopted. Cast-iron rings or Ramsbottom's steel rings, though not giving so little friction as gun metal, are generally preferred, because they wear well and are not so much affected by grit. The author's experience is that Ramsbottom's rings are tight, wear well, and do not require excessive tension. For great expansion in a single cylinder the tension of the packing should be dependent upon the varying pressure in the cylinder, as before stated.

In considering the question of stuffing box friction, the author would first observe that the amount of loss caused by it is only trifling if the packing is in proper condition and the gland has been properly fitted; but otherwise this loss may become enormous. The author is not aware of any comparative experiments showing the friction caused by the employment of various kinds of stuffing box packing, although that, doubtless, has also a great influence. But what all are aware of is the great wear on the piston rod through having the packing too hard. A careful engine driver avoids this, but every engine driver is not careful, and if he has many other things to look to, as is often the case, then the plain question arises whether it is not better either to use a packing that requires but little lubrication, or else to provide means for keeping the packing continuously supplied with a very slight amount of grease, which, as experience has shown, can be effected by greasing the steam before entering the cylinder. No other means are then found necessary for lubricating the slide rod or piston rod, and hard packings become an impossibility.

It is not intended to describe the various kinds of packing; suffice it to say that there are some which answer their purpose very well, some of them requiring little or no lubrication. The self-lubricating mineral packing has under some circumstances answered very well. Metallic stuffing box packing has been proposed and used. On account, however, of the great depths required and the expense and trouble attending its manufacture, it has never come into extensive use. Metallic stuffing box

packing would be a great boon, provided it answered its purpose. Mr. John Penn used to have one of his small shop engines fitted with metallic stuffing box packing, and the author believes he has so now.

With the view of placing the question of friction in the steam cylinder in a clear light, it is proposed to work out an example from experiments made. With a 12-horse horizontal steam engine of good make—the cylinder $11\frac{1}{2}$ in. by 16 in. stroke—the indicator diagram gave 2·155 lbs. nett average pressure for driving the engine alone. This, at 110 revolutions per minute, is equal to 1·99 horse-power. It is now proposed to calculate the friction of all the moving parts which can be conveniently got at, leaving piston and packing friction as the rest or balance.

Friction of Cross-head Pin.—2 in. diameter, mean pressure on same, say 200 lbs., $\frac{\text{connecting rod}}{\text{crank}} = 4 \cdot 75$, friction coefficient, $\cdot 0\ 5$; $1 + \frac{1}{4 \times 4 \cdot 75} = 1 \cdot 05$, which is a factor used several times: Mr. M'Farlane Gay's abbreviated formulæ used; then with 110 revolutions: $\frac{200 \times \cdot 065 \times 1}{12 \times 8 \times 4 \cdot 75} \times 1 \cdot 05 = \cdot 03 \times$ velocity, which $= \frac{6 \cdot 28 \times 110}{4 \cdot 75 \times 12} = 12 = 3 \cdot 6$ ft. lbs. only.

Friction in Guides.— $\frac{200 \times \cdot 07 \times \cdot 7854}{4 \cdot 75} \times 293 = 678$ ft. lbs.

Friction of Crank Pin.—$3\frac{1}{4}$ in. diameter $\frac{200 \times 1 \cdot 625 \times \cdot 065}{7 \cdot 63 \times 8}$ $\times 1 \cdot 05 \times \frac{10 \cdot 2}{12} \times 110 = 33 \cdot 3$ ft. lbs.

Friction of Crank Shaft.—Here we must add the weight of crank, fly-wheel, &c. (say 900 lbs.), then $\frac{1100 \times 1 \cdot 5 \times \cdot 065}{7 \cdot 63 \times 8}$ $\times 1 \cdot 05 = 1 \cdot 932 \times 110 \times \frac{9 \cdot 425}{12} = 160$ ft. lbs.

Slide Valve Friction.—The acting area exposed to pressure being 18 square inches, and friction coefficient 1-10th, then, $1 \cdot 8 \times \frac{4 \cdot 5}{12} \times 110 \times 2 \cdot 155 = 160$ ft. lbs.

Adding these results together gives nearly 1000 ft. lbs.; if we allow another 300 ft. lbs. for the rest of the friction, including air resistance of fly-wheel, but not piston and stuffing box friction, we see at a glance what an enormous proportion the latter bear

to the whole. $2 \cdot 155 \times 103 \cdot 9 \times 293 = 65646$ ft. lbs., out of which 64346 ft. lbs. for piston and packings, and 1300 lbs. for all the rest. It may be said that this is not a fair way of putting the case, as the friction of the load will alter this considerably when the engine is up to its power. Supposing then we say, as is actually the case, that this engine when working full power has a ten times higher average indicated pressure, the total number of foot pounds developed would be 656,460, out of which there are 13,000 for all the friction except piston and packings, the amount of the latter being as before 64,346. This, then, is a fair example, and here we find that out of the total friction of $64,346 + 13,000 = 77,346$, upwards of 4-5ths are absorbed by piston and packings. Here we are at the root of the matter, and if we want to economize, here is a wide field, for every foot pound lost in friction means a direct loss in money or fuel. It should be noticed that in this case the piston friction per square inch of the same, is (say) $1\frac{3}{4}$ lb. As the piston has two Ramsbottom steel rings, and their total frictional area is 36 square inches, we arrive at a friction coefficient of ·23 for continually but sparingly greased steam. A piston fitted with ordinary cast-iron packing rings would, for this case, have it $2\frac{1}{4}$ in. deep (instead of $2\frac{1}{2}$ in. steel rings), and the friction coefficient with same total friction would then become about 1-10th lb.

The aim should, therefore, be to reduce the piston and the packing friction to a minimum. The slide valve friction is proportionately small, it having been shown that when working at full power it is only 1600 ft. lbs., or about 1-39th of total friction. Nevertheless, if working with dry steam and without special lubrication, the slide valve friction may become considerable, even three times higher than stated. But worse than the friction itself are its results, namely, undue wear, scoring, &c., causing extra loss in fuel by leakage of fresh steam into the cylinder and the exhaust. The piston friction coefficient does not under the same circumstances increase in the same ratio, at least, not in ordinary unjacketed cylinders, in fact, were it not for the much greater friction it absorbs *per se*, it would not require extra lubricating material to the same extent as the slide valves, and for the following reason:—While the steam passes the slide valve little or no liquefaction occurs, but the opposite of this takes place in the cylinder itself, as the work done by the steam causes a proportionate amount of liquefaction, and this is the reason why many engines using rather wet steam and not having steam jackets work without special means of lubrication. The attraction of the walls of the cylinder tends to the deposition of a very thin film of water, which acts as a lubricant.

The case is, however, different if the steam is dry, when little or no condensation takes place, and it is then that greasing the steam is of importance. If this is not done heavy wear and friction of the piston will naturally result. It is better, for the sake of economy, to use steam just so much superheated that it retains its gaseous state during an expansion carried as far as circumstances will admit. The steam jacket will answer the same purpose.

In connection with this point it may here be of interest to mention an experiment, the particulars of which the author has obtained. A compound high and low pressure engine, which drove the machinery in the shop of Messrs. Humphreys, was tried both with and without a steam jacket to satisfy the firm of the utility of the jacket. The following are the results:—With steam in the jackets it took 22 lbs. pressure of steam in the boiler to drive the engine at 135 revolutions per minute; without steam in the jackets it took 29 lbs. pressure at the same speed; when the outsides of the jackets were well felted 12 gallons of water were condensed in the jackets; without the felting 15 gallons were condensed in the same time. The 12 gallons, or the greater part of it, went to supply heat to the steam in the cylinder, while the 3 gallons apparently were lost by outward radiation.

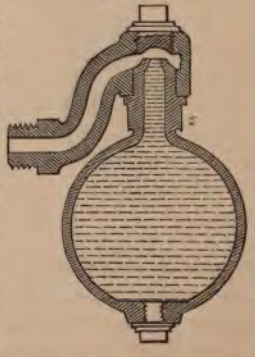
The waste heat of the uptake is often used for superheating purposes with or without steam jackets, but whether the one or the other is done, the saving in fuel is found to be very great. There is, however, one indispensable condition, namely, to keep the slide valve and piston from undue friction and wear, and the packings from getting hard and charred. Both these objects are attained in the most perfect manner by continuously greasing the steam before entering the ports. It is, therefore, highly necessary that all users of steam-power should fulfil the condition by having recourse to an efficient steam lubricator, of which there are several now before the public.

Having thus briefly glanced at the question of economy of fuel and the best means of effecting it, and having shown that steam lubrication is an indispensable condition, it remains to be seen that steam engines not built on economic principles are benefited by it. There is now scarcely an ordinary engine, using tolerably dry steam and cutting off at about three-fourths of the stroke, but which has some method of lubricating the steam in the cylinder. The ordinary means of lubrication consist of a grease cock on the cylinder, whereby the contents of a cup filled with oil or tallow are occasionally emptied into the steam. The effect of leaving a piston dry for a long time, and then injecting a quantity of tallow, has often been noticed.

The engine instantly takes a start and materially increases both in speed and power. This goes to prove that the lubrication of the steam is good for something. It therefore only remains to be seen which is the best way of lubricating. Shafting is generally lubricated by self-acting means, such as the slow capillary action of a wick, or by the needle lubricator. No one would prefer to empty the contents of the oil cup into the bearing at once. And yet that is precisely what is done in the case of the grease cock on the cylinder, with this difference, that the latter probably detracts far more from the economy of fuel than the former.

The subject of steam lubrication has of late years acquired some prominence, and locomotives are now generally fitted with self-acting means for continuously greasing the steam before it enters the valves. The principle also makes headway with stationary and marine engines. Those who have considered the subject argue that if they can save about 40 per cent. of the tallow that the common grease cock consumes, and at the same time have the additional and possibly far more important advantage of diminishing friction and wear and tear, why should they not do it? Fifty per cent. of fuel can be saved if engines are properly constructed, and a good price paid for them, but to save about 2 per cent. in friction, which means fuel, besides from 30 to 50 per cent. of tallow or oil used for piston and slide valve lubrication, is a far easier matter, and involves an outlay of a mere trifle. We have ingenious governors and heavy fly-wheels and counterweights for the crank and connecting rods to equalize the speed of the engine, let us not lose sight of a point which may appear trifling, but which in reality has something to do with the steady and even working of the engine, as experience has shown. It would be both superfluous and tedious to enumerate all the lubricators proposed or used for greasing the moving parts in the steam cylinder, the more so as all these appliances are now advantageously superseded by lubricators acting on the principle of continuously greasing the steam before it enters the slide valves. One of the first lubricators of this class is that invented by Mr. Ramsbottom, the locomotive superintendent at Crewe. Fig. 1 shows the form in which this lubricator is used upon locomotives. The principle on which it acts is the following:—A swan-neck pipe being in communication with

Fig. 1.



the steam in the steam pipe, causes a steady flow of steam into a sphere which is filled with tallow to the top of the inner pipe. The steam continually condensing, especially when a current of air is sharp against it at high speed, causes it to fall to the bottom as water, because it is heavier than tallow in the proportion of 5 to 4. A certain amount of tallow is thus continually displaced and forced to overflow into the steam pipe, where it mixes with steam entering the steam cylinders; the steam is thus continually greased. There are no means of regulating this action, but this is not found so very requisite for locomotives. The case is, however, different when we come to apply this lubricator to stationary or marine engines. For such purposes it is necessary to lead the steam to the lubricator (seen at Fig. 2), through a long pipe in the engine room, that pipe then supplying the necessary condensing surface, or better still, to

Fig. 2.

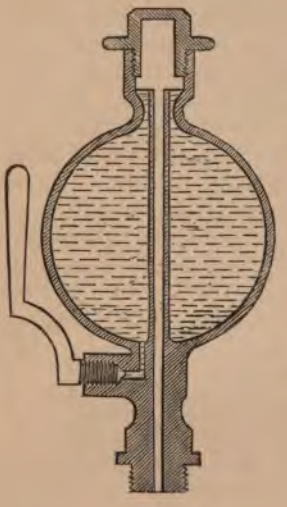
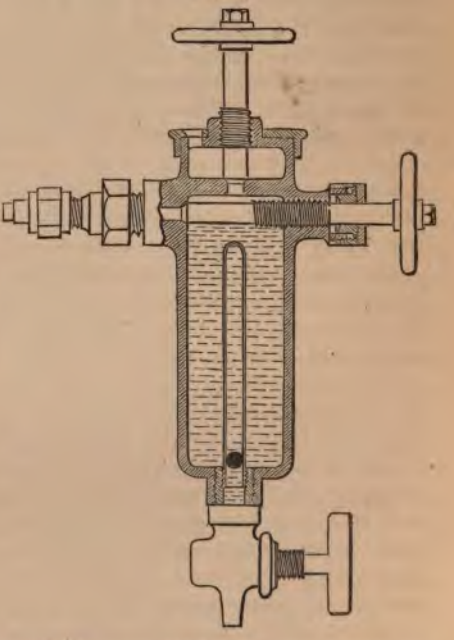


Fig. 3.

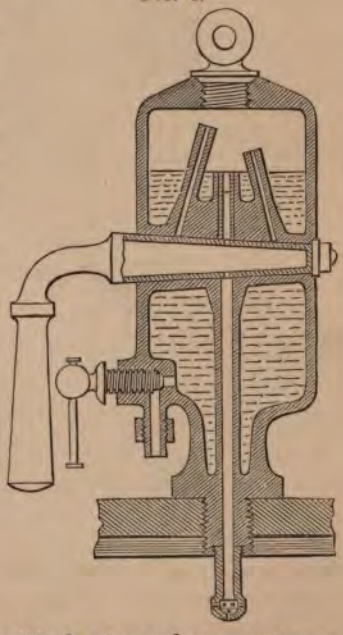


place the lubricator in a cool place outside the engine room. The apparatus, however, does not seem very well adapted for engine room purposes, though it answers for locomotives.

The next lubricator is Roscoe's, which is shown at Fig. 3. It acts by condensation of the steam and the consequent displacement of the tallow. It consists of a small hollow vessel

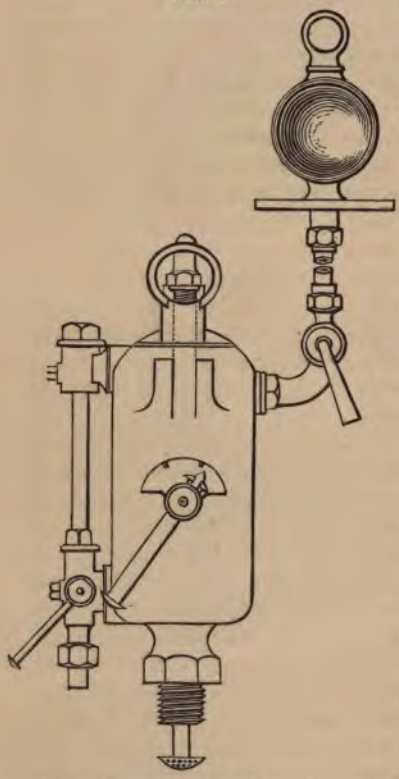
with a steam connection on one side, tallow inlet at top, and waste cock at bottom. The opening is surmounted by a metal cup with open top, having a lid for filling the tallow; a bridge across the same with a screwed hole in it takes the screwed spindle of a jam valve, which fits a seat in the partition between the lubricator itself and the filling cup. A tube is fixed to the end of the screwed spindle, and reaches to within about two inches of the bottom of the lubricator. The inventor also claims a peculiar function for the central pipe, for he says that when the engine is running down an incline with the steam shut off, the heat causes the air in the tube to be rarefied, and thus obtain a certain pressure which again forces the tallow into the steam pipe and thence into the engine. The action of this pipe does not seem very clear, the more natural course seems to be that the whole of the lubricator when steam is shut off, and while running at any speed at all, should get comparatively cold, and the tallow have a decided tendency to stop where it was. However that may be, these lubricators are extensively used on the Midland Railway and on several others, as well as on many stationary and marine engines, and, the author believes, give satisfaction. The means of regulation, it will be observed, consist in controlling the amount of steam entering by the screwed jam valve opposite the steam pipe on the apparatus. That the inner pipe, as claimed by the inventor, should prevent the water at the bottom of the apparatus from freezing in the coldest climates when the engine is at work seems claiming too much, for the very small quantity of air contained in it which is compressed to a volume of the size of a thimble, if there at all, can have no influence on the quantity of water continually entering. The capacity for heat is much larger in water than in air pound for pound, and the quantity of air contained in the inner tube of a No. 3 lubricator containing about a pint of tallow is only about 1 cubic inch, and with 5 atmospheres pressure only $\frac{1}{5}$th of a cubic inch, weighing $\frac{1}{100}$th part of a pound.

FIG. 4.



The Wilson lubricator, shown at Fig. 4, has three different tallow levels each with corresponding ports or holes in the cock and its shell, thus giving three sizes of condensing surface, a means of regulation perhaps sufficient for some cases; but in practice something closer is generally required, and that must be attained by throttling the steam inlet through the regulating cock. It acts on the same displacement principle as most of the others in common use. A jam valve with screwed stem serves as blow-off. Should the place where it is fixed be too hot so as not to condense sufficiently fast, a globe is attached to the steam supply pipe, as shown in Fig. 5, which will afford the requisite condensing surface. This ingenious and simple remedy is not mentioned in Mr. Wilson's patent, and will no doubt answer for other lubricators constructed on similar principles when placed in a very hot position. One fault attached to the instrument made with a water gauge is that the latter does not at all times indicate the true level. The bottom of the gauge is connected to the lower part of the lubricator, but the top is in connection with the steam space above the two lower tallow levels, and any variation in the quantity of tallow and water contained—which, of course, when the instrument works, are continually changing—is not indicated, because the water locks the tallow in the glass. It is only by blowing the glass out and wasting the tallow that the true state of this instrument can be ascertained, as while the glass shows full tallow, there may be little or none left. This is not an oversight of the inventor's, but is inherent in the construction because of the three different tallow levels the gauge only shows when working at the upper one, the one having the smallest condensing surface. In

FIG. 5.



these lubricators a quantity of tallow can be let in at once, namely, all the tallow contained above the centre of the regulating cock, but the instrument then wants refilling again up to its ordinary tallow level.

Clements's lubricator is of simple construction. A pipe from the engine steam pipe conveys steam up through the lubricator, entering from the bottom and discharging over the tallow level, also provided with a cock for regulating the supply of steam to the apparatus which acts on the displacement principle. Another inside vertical pipe, which must reach to and determine the tallow level, carries the tallow away to the engine steam pipe or slide jacket. This pipe is also provided with means for regulating. The steam is supposed to pass through the tallow and carry it along with it. A gauge glass is provided in the larger sizes. A blow-off cock is provided for discharging the condensed water or foul tallow. These lubricators seem to give satisfaction, and are simple enough; the fitting them on is more troublesome, as they require two steam connections.

A very ingenious lubricator was patented last year by Mr. Schauwecker. It is fixed on the cylinder, and consists of a cup with an outer jacket to keep it warm. A central pipe enters from the bottom, and reaches nearly to the top. Near the bottom this pipe is in communication with a capillary pipe or passage, too small for the oil to force itself through except when at the latter part of the stroke the pressure gets lower in the cylinder than in the top of the grease cup; at that moment a small quantity of grease is injected. A filling cup is provided as in the old-fashioned grease cups.

Storer's lubricator, patented in 1866, deserves some notice, because it has been brought prominently before the public. The lid of the lubricator is fixed by means of a bayonet joint. A screw passes through the lid, and its end is tightened down on a soft metal seat; this is for shutting off the lubricator. A strainer or cage fits over the bottom outlet, which has a cock below for regulating the quantity of steam coming in and grease passing out. Supposing this grease cup be filled with suet, which is the material it is worked with; the suet will first melt, and the light oil which is present in it will be brought forward and in a profuse quantity enter the cylinder. This is an operation requiring but very little time; but the suet will remain in the grease cup for many hours after that, but only the gelatinous part of it, which partakes of the nature of glue and is gradually being distilled off, and is of no use to the cylinder but rather does it harm. We then see that the action of this lubricator is very imperfect, very irregular, and in point of fact nearly as barbarous as the old grease cup; nevertheless

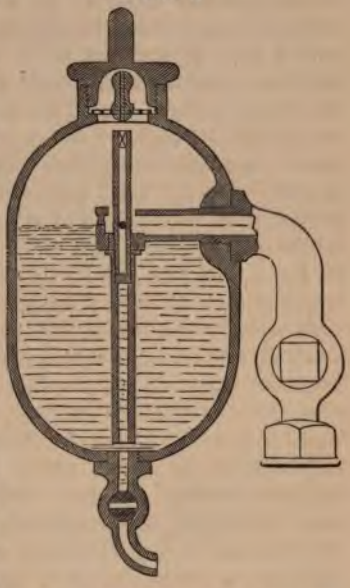
it has been brought widely into use, and maintains its position on account of its cheapness and simplicity.

Attwood's tallow pump, patented in 1864, was a step in the right direction; though it has since been superseded by better means, it well deserves a notice. The body of the pump is provided with a steam jacket to keep the tallow hot, otherwise it is fitted like an ordinary pump with valves and piston, which latter is worked up and down by being connected to some reciprocating part of the engine. The point of attachment is made variable, to regulate the quantity of tallow injected. This apparatus ranks intermediately between the old-fashioned way of injecting the whole contents of the grease cup every two hours or so, and the modern way of continuously greasing the steam. It would even now be useful were it not for the often troublesome matter of keeping the valves in proper order and of arranging its connection to the engine, and for the circumstance that the engineer in charge is too apt to forget all about the tallow pump. Finding that it gives too much tallow if always at work, he throws it out of gear, and often forgets to throw it into gear till too late. Engineers in charge of flour mills and other works where the power is variable, sometimes say that a tallow pump is the right thing or else the old grease cup, because the engine often labours hard when the stones are pressed together a little too much, and a sudden injection of tallow is apparently beneficial, the engine at all events recovering its speed; a little consideration has, however, persuaded many of them that this view of the case is quite wrong. If such a quantity of tallow is required all at once, and does produce such a marked effect, what must be the state of the piston and other internal parts? The answer is, "Very much too dry." But this would never happen were the steam properly lubricated. There is no surer way of clogging the piston rings, &c., nor a more likely way of starting red-lead joints than by injecting a quantity of tallow at once. If a mill engine labours occasionally, the power is not large enough to overcome the resistance, and it is the wiser plan to improve the condition of the engine and thus increase its actual power, than by dosing it with what might be likened to a strong dram of neat spirits—all very well in extreme cases, but very bad taken habitually.

It will have been observed that all the lubricators hitherto described are regulated more or less by throttling the steam admission to them, a consequence of which is that the least dirt is apt, as experience has shown, to stop their action altogether. Within the last two years another lubricator, acting on the displacement principle, but yet working in a different way to the others, has been introduced. It is the invention of Mr. Gamble.

The principle of this lubricator, shown in Fig. 6, is as follows:—The steam enters from the steam pipe, passes over the surface of the tallow, which it absorbs and retains in the shape of vapour charged with tallow; this is true as regards part of the steam, but the other part condenses and falls to the bottom. There is consequently a continuous charging of the entering steam with tallow, a continuous condensation of entering steam, and a consequent tendency to rise in the level of the tallow floating on the water. To restore the equilibrium one of three things may take place. There may be a continuous return flow of vaporized tallow from or near the surface back into the steam pipe, and thence into the cylinder, or a continual flow of condensed water if it could be siphoned out from the bottom, or a continual flow of a mixture of both. In his latest modification Mr. Gamble has contrived a simple means of accomplishing the object, and at the same time making it a perfect means of regulation. The steam enters from one side through a pipe, and rises into the steam space; part of it falls to the bottom as water, while part of it may flow back as greased steam or vaporized tallow. The steam pipe, at its termination at the centre of the apparatus, has a small hole at the tallow level for the entering of the steam and the egress of the greased steam. The steam pipe has a siphon pipe screwed into its bottom reaching nearly down to the bottom of the lubricator. Into the inside top of this siphon pipe a small pipe, the regulating pipe, is screwed, which has a small hole in its side and has plenty of play round it when it passes through the steam pipe. If this pipe is screwed down so as to have the hole in its side at the same height as the steam or tallow hole, then singularly enough, no doubt owing to the capillary attraction, the water will take the preference and will continue to be siphoned out from the bottom as fast as it comes in and condenses, so that little or no lubrication takes place. On the other hand, if the regulating pipe is screwed up so that its hole comes somewhat over the steam or tallow hole, then no water will be siphoned out from

Fig. 6.

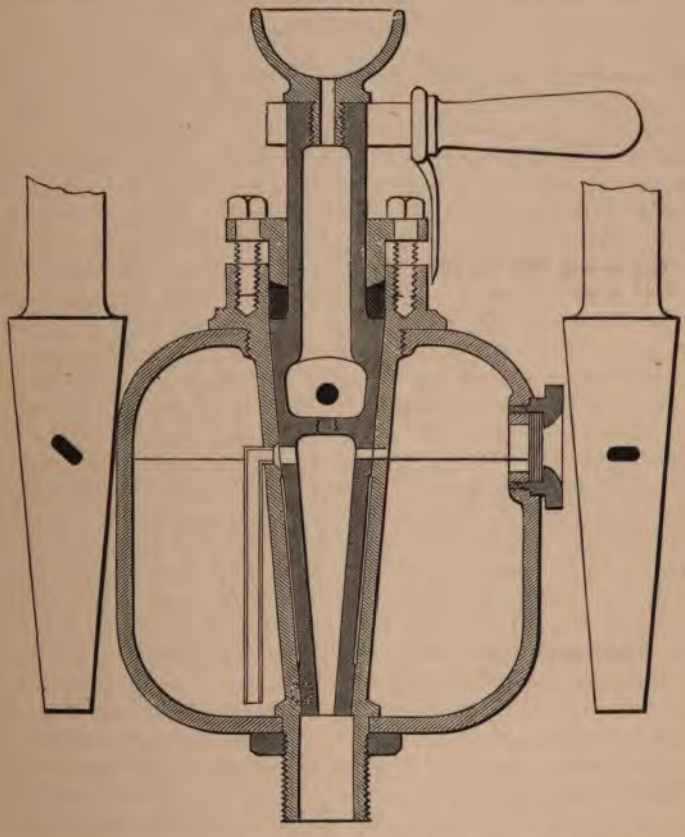


the bottom, and a very plentiful lubrication with tallow takes place. In any intermediate position partly tallow and partly water will overflow into the steam pipe. This can be regulated to the greatest nicety. In one case, for instance, the engineer in charge said that if the lubricator emptied itself in ten hours, it would do. It was set to do it, and did it. He found that he had more tallow on his rods than he wanted. It was regulated accordingly, and then used its tallow in fifteen hours. He found that he had got more than enough lubrication even then, and it was accordingly set so as to empty itself in twenty-two hours. As the mill works twenty-two out of the twenty-four hours, that just suited him; he fills the lubricator once a day while oiling round, and does not trouble himself further about it, for it will just use its tallow by the time he has done. These lubricators will work in very hot engine rooms without special means for condensing the steam; the means of regulation are such as not to offer temptation for meddling, for the jam screw must be taken out of the top after the steam has been shut off; a small crutch key is fitted into the top of the regulating pipe, and by turning it a trifle up or down more or less tallow is fed into the steam. But there is no regulation by throttling the entering steam by means of the steam cock, and neither is there any regulation by contracting the opening for the overflow of the tallow. These lubricators are simple in construction, and they have no working or wearing parts that require looking after, or setting, or renewing; and when once regulated they are always set, no further trouble being incurred than to draw the condensed water off and fill afresh with tallow. As soon as the engine has started, its action begins at once. They are now working successfully on marine engines, locomotives, stationary and portable engines, and are made in suitable sizes for all purposes.

The same principle is carried out in a different way by another arrangement, shown in Fig. 7. As steam users sometimes ask for a lubricator with which they can at any time vary the supply of tallow, the inventor contrived this arrangement; the author contends, however, that this is quite unnecessary, except in very few cases. As before explained, if an engine is constantly and properly lubricated, there is practically no need for constant regulation of the tallow supply. It is made in the shape of a hollow plug cock passing vertically through the lubricator; the plug has several small ports with corresponding holes in the plug shell, which is fitted with a siphon pipe leading to the bottom of the lubricator the same as the others. To vary the respective vertical heights of the tallow overflow and water overflow, the plug has a slanting slot corresponding with a hori[illegible] slot in the shell; and by turning the cock to any

of the pointer divisions on the outside of the lubricator neck, these levels can be varied to such an extent as to cause the

FIG. 7.



same action as above explained with reference to the former class of Gamble's lubricators. The same objection may, however, with justice be urged against this last arrangement as against some of the lubricators by other inventors which have been previously described, namely, that any cock arrangement in course of time gets out of order by constant wear.

The author has now, it is hoped, shown that steam lubrication is a subject well worth taking into account in steam engine economy; also that the continuous system is the only correct one, and ought to be more generally introduced wherever the old-fashioned and wasteful intermittent system has been found

better than no lubrication at all. It is therefore important that engineers should more generally take notice of these facts, which form small links in the large chain of steam economy.

DISCUSSION.

Mr. P. F. NURSEY said that in the paper which had just been read lubrication by means of condensed steam was credited originally to Mr. Ramsbottom, of Crewe. In 1858, Mr. Stirling, then of Kilmarnock, but now of Doncaster, read a paper before the Society of Scottish Engineers, in which he described a lubricator acting upon the same principle. The objection to the apparatus described by him was that there were no means of regulating the supply, and also that it required replenishing several times when the engine was running a journey. Next in the order of date came Mr. Ramsbottom's lubricator, which was patented in 1860. In that, as Mr. Jensen had observed, Mr. Ramsbottom claimed the principle of lubrication by condensed steam. Now, it was quite clear that Mr. Ramsbottom could not claim anything of the kind, inasmuch as Mr. Stirling, whilst engineer to the Glasgow and South-Western Railway, had some two years previously to Mr. Ramsbottom's patent described a lubricator worked by condensed steam. Looking at Ramsbottom's lubricator as represented in Fig. 1, it appeared to him (Mr. Nursey) that the objections to it were that it was partially inefficient, being constructed upon the same principle as that described by Mr. Stirling was, and it was open to the same objection—that there were no means provided for regulating the supply. The practical result of that was that sometimes the contents of the lubricator were emptied at one stroke. Following on, then, in the order of the paper, the next lubricator was Roscoe's. That was fitted with a regulator and also with a central tube, which Mr. Jensen did not sufficiently explain. The air in the tubes was acted upon by the steam passing through the valves, and when the engine was running the action of the air imparted a constant motion to the lubricant and to the water beneath it, and so preventing it either stagnating or freezing. Then, when the steam was shut off, supposing the engine to be running down an incline, the sudden expansion of the air would drive some portion of the lubricant out of the chamber into the steam pipe and cylinder, and so afford a means of lubrication whilst descending the incline, when the steam would be shut off. There was a lubricator which had just come under his (Mr. Nursey's) notice, and which was the invention of a Mr. Kessler. It was patented in 1866, and a wick was introduced into it, but it would only answer when the steam

was shut off, as it was only to be used during that time. Mr. Kessler argued that no lubrication was required when steam was on, steam being a sufficient lubricant in itself. He (Mr. Nursey) thought, however, that the high-pressure steam used in the present day was so dry and so heated that it certainly required lubricating when the steam was on as well as when the steam was shut off—possibly more under the former condition. He (Mr. Nursey) therefore failed to see the great efficiency of Kessler's lubricator. Gamble's lubricator appeared to be—taken generally—a very efficient one; but when the author of the paper stated that inquiries were constantly being made for those lubricators—but they were required to be fitted with regulators—it appeared that there must be some inefficiency in the apparatus when worked without the regulator. It was either too delicate in its construction, or else it was too incomprehensible in its action; therefore the very fact of a regulator being required appeared to him to show that there was no great superiority in Gamble's over Roscoe's lubricator. With regard to the lubricator shown by Figs. 4 and 5, that seemed a little complicated and went back to the old principle. With respect to the entrance of dirt, he did not see why there should be any fear of that in Roscoe's lubricator; in practice, he was not aware that the objection had been raised. It was used on some thirty lines of railway in Great Britain and on a great number of railways on the Continent, and in America and Australia. Amongst other lines, he believed it was used on the North London Railway, and he hoped their President would be able to tell the meeting whether it was efficient or not—whether dirt entered it or not. In that lubricator the principle of regulation appeared to be very nicely adjusted. The engine driver could use either large or small quantities; and unless they opened the regulator to an unnecessary extent, there was no fear of the whole contents blowing off at once, as in some other lubricators.

Mr. Schonheyder said that the question of steam piston friction had been raised by the author of the paper; but he had not been able to make any actual experiments on friction; and although he (Mr. Schonheyder) did not doubt the accuracy of the author's calculations as to the friction of the various parts of the engine, yet he thought it was a calculation which was very difficult to make and liable to very great errors. The state of the lubricant and the amount of friction in each case might be very different from what was assumed, and the result arrived at would therefore be very erroneous. It seemed to him that if the question was to be settled, the steam ought to be put upon one side of the piston, and apparatus upon the opposite side, by which the direct pressure required to move the piston could be

measured. Without that they could not arrive at any accurate knowledge of the friction of various pistons. The author stated in his paper that the friction varied directly as the diameter, which was correct; but the author also stated that it varied as the width of the ring, which was not correct, for the friction varied as the total pressure upon the rings, because friction was independent of surface; in fact, so far it was independent of diameter, as the friction depended upon the total pressure upon the rings, and not upon the surface; and he did not see why it should be twice as great in a piston that had a 2-inch ring as in one that had a 1-inch ring, although the surface was twice as great, unless the pressure was twice as great also. Mention had been made of Ramsbottom's packing rings, of which he (Mr. Schonheyder) had had some experience, and he found them wear exceedingly badly in some cases. In a great many instances they would not work for more than two months, in which time they were worn completely through. It was a difficult matter to set and adjust them so that they would wear equally. On the other hand, with a few engines, they lasted a great number of years. In one 16-inch cylinder engine they had lasted five years, working twelve hours a day; and in large engines, with about 52-inch cylinders, they had lasted as long as eight years. The great fault was that they were made too light, and their name was deceptive. They were commonly called steel rings, but they were nothing of the kind, or at least it was a very peculiar steel; it would not harden if it was immersed in water after being heated to a bright red, and it would bend like soft iron. With respect to lubricating, it was the right thing to do, to grease the steam continually. Those lubricators that required a very fine adjustment were liable to be stopped up. He thought it was an advantage in Gamble's lubricator that whichever way it was adjusted, all the passages were large, and none of them were diminished by the adjustment, and therefore they were not liable to choke. The grease ought to be introduced into the centre of the steam pipe, not on one side of it, so that it was at once enveloped in the steam, and carried away in a body.

Mr. Hodge said that the best method of lubricating stationary engines was to carry the oil in two cups, one on each side of the cross-head, and inject the one for one half the day and the other for the other half. A small tap was bored through the cross-head by which the consumption of oil could be regulated. He objected to the use of tallow, because it accumulated in the cylinder, and had to be removed from thence in a condition resembling glue, but which was really stearic acid, which be- [illegible] d and choked up the cylinder and steam passages, the

oleic acid being driven off by the steam pressure. A lubricating material had been introduced from America which answered well with high-pressure steam. It was a mixture of paraffin and common oil. He considered the best packing to be that made of Babbett's metal in rings, which he had used with great success.

Mr. OLRICK said that within the last few weeks a new material had been introduced for making friction surfaces, and by which means lubricators were dispensed with. He did not know the composition of the material, but it was stated that an engine with gudgeons of that material made 5000 revolutions a minute, and no lubricant whatever was used or required.

April 4th, 1870.

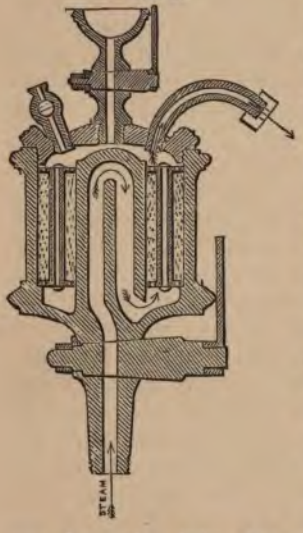
WILLIAM ADAMS, PRESIDENT, IN THE CHAIR.

FRICTION IN STEAM CYLINDERS.

ADJOURNED DISCUSSION.

Mr. SPENCER opened the discussion by referring to a lubricator (shown at Fig. 8), which he stated took precedence of Mr. Ramsbottom's. This was the invention of a Mr. Marks, although it was patented in July, 1860, in his (Mr. Spencer's) name, whilst Mr. Ramsbottom's was patented in October, 1860. Mr. Marks' lubricator, like the others, had a close cylindrical vessel in which was placed a porous material, held together by perforated plates, with a view to receive the oil which was admitted from above, when the porous material became saturated. The steam was admitted at the bottom and proceeded upwards through the porous matter, and then went to the part that was lubricated. It was stated that this answered exceedingly well. The essential difference between that and Mr. Ramsbottom's lubricator was, that in Mr. Marks' the steam was brought into the cylindrical vessel, filled with porous material and saturated with the oil, and then passed through the steam pipe to the part to be lubricated. In Mr. Ramsbottom's, the object was effected by the condensed water raising the oil, and so passing it into the part to be lubricated.

FIG. 8.



Mr. OLRICK said that he considered the amount of friction, which the author of the paper had estimated at 2 lbs. per square inch of the piston, was too much. He placed before the meeting some indicator diagrams which he had lately taken from an engine having 16-inch cylinders 30 inches long, and

after having taken diagrams with about 70 per cent. of the work, he took the full work of the engine, and after that he took the friction diagrams, and from one of those, No. 8, the friction of the whole engine was 1·4 lb., and in another case 1·5 lb.

Mr. SCHONHEYDER said he had heard it mentioned that some engine makers in America endeavoured to reduce friction by scraping and surfacing their slide valves. That was a correct principle, but however accurately a slide valve was scraped when it was cold, the same shape would not be retained when it got hot and had the pressure of steam upon it. He had seen many instances where valves had been scraped to a very true surface when cold, but after the steam had got upon them they altered materially in shape, so that, practically, the great labour spent in getting a fine surface was wasted. With respect to the remark made as to the depth of the piston, he thought it was impossible to give any rule for it. They were made of various depths for many reasons: in an engine upon which there was a very high pressure per square inch, the piston had to be made very deep, and that was done partly to give the rod a good bearing in the piston, and partly because the high pressure upon it required great depth to give it strength.

Mr. HENDRY considered that Ramsbottom's lubricator was more simple and certain in its action than the others which had been referred to, although he did not consider that Ramsbottom's rings were quite so good as some other forms of packing, of which there were many varieties. They would all have a certain effect on the friction of the steam cylinder. He considered that the friction of the piston in the steam cylinder was not such an important matter as that of the friction of the slide valve, and how to lubricate the surfaces of the slide valve itself. He believed that in the cylinder the condensation of the steam in contact with the metal acted as a lubricant, for when the steam was absent then came the effects of friction. Therefore, when there was no steam in the cylinder lubrication was required, although it was always wanted in the slide valve, which was the great seat of friction. The proper place therefore at which to apply lubrication was the slide valve.

Mr. NURSEY said he was surprised to hear the last speaker say that the lubricators which followed Mr. Ramsbottom's were less to be preferred than that. Undoubtedly Mr. Ramsbottom's was a very simple one, but its simplicity was only equalled by its inefficiency. It was a well-known fact, that it constantly emptied itself when started to work. The great advantage of those by which it was followed appeared to him (Mr. Nursey) to be the capability of regulating the supply of the lubricating

material, so that a simple lubricator like Ramsbottom's ought not to be preferred before others if it had nothing more than its simplicity to recommend it.

Mr. GALLOWAY asked whether the admission of cold atmospheric air by the steam ports, and which would at once act upon the slide valves, would tend to diminish the friction of the slide valves.

Mr. B. LATHAM said that a large amount of friction arose from the metals used for the purpose of packing. The author of the paper had incidentally alluded to a certain packing, but that packing was really in his (Mr. Latham's) opinion a very bad one. In the case of gun-metal packings, especially in slide valves, he recollected some eight years ago having an 18-inch cylinder horizontal steam engine fitted with a gun-metal slide valve. The author implied that gun metal was one of the best metals for packing. If it was good in a steam cylinder it ought to be good in a slide valve. The effect, however, in his engine was that the engine absorbed two-fifths of its power alone in working the gun-metal slide valve. Directly lubrication was tried the engine began to groan, and the lubrication of the slide valve had to be discontinued, because of the nuisance the noise became to the neighbourhood. If that was the result in a steam chest the drawback must be much greater in a cylinder where there was a much larger area. In his engine the gun-metal slide valve was taken out and a plain cast-iron slide substituted for it, which was found to save half the power, and to cause a considerable reduction in coals. On lubricating, the engine worked as easily as possible. Steel rings were more expensive than rings of cast iron, and he thought that two cast-iron surfaces working together would probably be found more economical in the first instance.

With regard to the various lubricators there was no doubt that each one had its advantages, but he thought the question of the lubricator was a minor consideration as compared with the principles which should govern the construction of machinery. The great point was first to ascertain what metals were best to use so as to avoid friction; then came the second point, as to what form of lubricator should be used. Many of the lubricators exhibited were complicated The great value of all lubricators was simplicity. In the early engines the lubricators were just as efficient as those applied in modern practice. In former years little or nothing but hemp packing was used, yet the author stated that hemp was one of the worst materials for packing. The records of engines in Cornwall, however, showed that as modern innovations had been introduced, so the duty of the engines had fallen off. If, however, lubricants were to be

used, he thought that suet should be supplied in an ordinary cylinder of simple form. The steam passing through it would convert the suet into an efficient lubricant without the expense of a complicated apparatus. The question of friction in the steam engine, however, required further elucidation and experiment, more especially with regard to the materials to be used in the packing of steam cylinders. Very much, however, depended upon the accuracy of the workmanship. That was a point of special importance, and it was far more economical to give a good maker double the price for an engine than to give a low price to a maker who cared nothing for precision or nicety of fitting in the engine.

Mr. A. Williams said that a new description of piston was being tried at the Southwark and Vauxhall Waterworks, by Mr. Quick, and which promised to be very successful.

Mr. L. Wise said that Mr. Quick's piston consisted of a number of small pistons working in the body of the main piston, the small pistons being connected by T pieces and intermediate rings with the packing rings, so that the pressure of the packing ring upon the surface of the cylinder was from time to time in direct proportion to the difference between the pressures on the respective sides of the main piston. The result of the application of one of those pistons of 55 inches diameter in a single-acting pumping engine at the Southwark and Vauxhall Waterworks at Battersea had been a reduction in friction during the down-stroke equivalent to a steam pressure of 1 lb. per square inch, whilst the relief afforded to the piston during the up-stroke had resulted in an absolute gain of 10 feet in the height to which the water was raised.

Mr. Olrick asked if any of the members had any experience in steam-packed pistons. By steam-packed pistons he meant those in which steam was admitted through the side of the piston by means of a small valve at every stroke and pressed on the ring, which for the time being made a tight joint, and when there was no steam in the cylinder the ring collapsed again and there was no friction.

Mr. Spencer said some years ago pistons similar to those described by Mr. Olrick were tried on the Brighton Railway, but were discontinued, as they were not found to answer. They were patented by Mr. Maunder.

Mr. Galloway wished to submit a plan for obviating the friction in the slide valve. Friction was the result of heat between working surfaces, and lubricants had simply the effect of reducing the heat, and in proportion reducing the friction. There was no mode of packing which would obviate friction, and there was no kind of lubricant which could be so effectively applied

as to overcome it. He therefore proposed to force cold atmospheric air by a connection with the steam chest through the ordinary steam ports with the steam. He believed that plan was based upon natural laws, and that the air would condense the steam so far as to obviate friction, and that the result of the expansion of the air would be in favour of the working power of the engine.

Mr. LATHAM asked what arrangement Mr. Galloway used to get the atmospheric air into the cylinder?

Mr. GALLOWAY said he proposed to connect the cylinder with a pipe from the accumulator in which the air was compressed. The compression would be effected by an air pump worked from the engine. A portion of the air would be carried to the boiler, and would work out his theory of the power of combined air and steam.

Mr. LATHAM said it appeared to him that it was impossible to realize any substantial results from such an invention. He need not point out the great economy that resulted when Watt isolated the condenser from atmospheric air. If, however, atmospheric air at the ordinary temperature was to be admitted into the steam cylinder in conjunction with steam, and not only so, but that the air was to be forced into the cylinder by a power which was taken off the engine, no economy could result.

Mr. OLRICK asked how Mr. Galloway would prevent the air that went into the cylinder from destroying the vacuum in condensing engines? He would also ask what amount of power was required to pump air of the necessary high pressure into the accumulator, and what was the relative proportion between the gain and the expenditure of power?

Mr. GALLOWAY said that to answer Mr. Olrick's questions thoroughly would occupy a considerable time, which he was not then prepared to do, but would do so on a future occasion if the opportunity was afforded him, when he could prove that there were many advantages from the combination he proposed. In reply to Mr. Latham he would state that the cold air would condense the steam to a certain extent, and so prevent friction in the slide valve, which would result in economy, and just in proportion as the heat in the steam was condensed by the application of atmospheric air, so the air itself was expanded into a motive power.

Mr. LATHAM said that atmospheric air could not possibly be condensed to a pressure greater than that which was in a steam cylinder without the air giving out its ordinary temperature, and then, if expanded to the temperature of the steam in the cylinder, it would absorb heat just as in ordinary freezing machines, where ice was made on that very principle. It was

therefore impossible for Mr. Galloway to obtain the power he had stated.

Mr. GALLOWAY said that was precisely his argument. The atmospheric air would have the direct effect of condensing the steam, but the effect of the condensation would tend to expand the air and convert it into power.

Mr. JENSEN, in reply said, with reference to Mr. Schonheyder's remark that the Ramsbottom rings would sometimes not last more than two months, he thought that must be a very exceptional case, because he had frequently used Ramsbottom's rings and never had such a result. He agreed with Mr. Schonheyder that the lubricant should be introduced into the centre of the steam pipe, and all the lubricators that had been introduced did deliver the lubricant in that way, so that the steam in passing carried along the lubricant and the two became incorporated. It was no doubt an advantage in Gamble's lubricator that it had no contracted openings in which dirt might enter and stop its action. Ramsbottom's lubricator possessed the same advantage. There was an objection to tallow as a lubricant because it could not be obtained pure commercially. There were acids contained in it which seriously injured the valve faces if it was used in any quantity, so that oil was preferable. No doubt suet was a pure lubricant, and very applicable as Mr. Latham had stated; but it would be better to melt the suet down first, so that those parts which formed into a glue should not be used. With regard to the question of friction, he had shown in his paper that the friction of the piston and of the slide valve formed the principal part of the friction in the engine, and that all the other friction was as nothing compared with that of the slide valve and piston. Mr. Olrick had stated that the piston friction in one case in which he made experiments, amount to only 1·5 lb. and 1·4 lb., but the engine Mr. Olrick referred to was nearly double the size of the one mentioned in the paper, and two engines were never found alike, because the least difference in the tightness either of the stuffing box packing or of the piston packing made a great difference in the result, and it was quite possible that some engines might work with even less friction than that stated by Mr. Olrick. He (Mr. Jensen) knew of cases where the piston friction was more than 3 lbs., so that no certain rule could be laid down. Another thing was, that if the engine Mr. Olrick spoke of was to work at a low pressure, the tension of the piston rings need not be so strong, so that 1½ lb. per square inch would probably be the friction developed, but the engine to which he (Mr. Jensen) referred was perfectly tight at 85 lbs., so that 2 lbs. per square inch would

be about right for that engine. With regard to the depth of the packing, it was also impossible to lay down any definite rule for that, although no doubt, for horizontal as well as for oscillating engines, it ought to be deeper than for vertical engines. He agreed with Mr. Hendry that Ramsbottom's lubricator was the simplest, and was a very good one for locomotive purposes, but he (Mr. Jensen) held that for other classes of engines it was not the best, as there were no means of regulating it. Mr. Nursey had also, in his remarks, corroborated his (Mr. Jensen's) views in that respect. With reference to the case stated by Mr. Latham, in which he found gun-metal slide valves of no use, that might possibly be so, but he (Mr. Jensen) had used gun metal for slide valves which had never groaned, but which worked up to a good face. He had, however, seen the face of a gun-metal slide valve that was scored to a serious extent, and if a slide valve was made of very soft gun metal, no doubt it would be very much scored. A hard metal should be used which would give a very different result. But there was no occasion for using gun metal at all, because good cast iron of a close texture answered every purpose, and was very much cheaper. He had known gun-metal piston rings which had worked well for about ten years and were then in good condition, so that to say from a single instance that gun-metal rings or gun-metal packings were of no use was not quite fair. He thought the piston of Mr. Quick which had been alluded to was rather complicated. If any of those small pistons became choked with dirt or the gummy parts of the lubricating material, then the whole piston would be useless. With regard to scraping the valve face when cold, and then scraping it afterwards when hot, there was no doubt that in large slide valves it was very desirable indeed, because valve faces were sometimes warped very considerably by the heat, and he believed it was usual in some establishments to take them out afterwards and take off the hard places after they had been under steam some time.

The PRESIDENT said that the members were very much indebted to Mr. Jensen for the paper he had read, which had elicited much useful information in the discussion. The amount of friction in the pistons and valves of an engine was very great, and the investigation of the subject would, no doubt, result in some means of reducing that friction. In his own practice as a locomotive engineer he was specially aware of the importance of that subject. The slide valves in a locomotive engine, which were made $\frac{3}{4}$ths of an inch thick in the first instance, wore down to $\frac{3}{16}$ths or $\frac{1}{8}$th of an inch thick in twelve months. That would give some idea of the friction which took place there, and the

loss of power and wear and tear consequent upon it—wear and tear not only upon the valves themselves, but on the mechanism that served to move them. To prevent or reduce that friction there were several contrivances. There were equilibrium valves, and many engineers had worked at them for years, and had tried to bring them out in a practical shape; but his experience was that there were considerable difficulties in the way of using such things in connection with very high-pressure steam. The first thing to be studied in a steam engine was to make it efficient for the work, and many of the equilibrium valves that had been tried were found somewhat to impair the efficiency of the engine. They might, perhaps, lessen the friction of the slide valve itself, but then engineers were obliged to look at the general result. The question was, taking everything into account, whether an engine was more efficient and economical with an equilibrium slide valve than with an ordinary one. He had tried equilibrium slide valves, which were very easy to handle with full steam on and the regulator fully open, when the engine might be reversed with the greatest ease, and standing on the engine in the shed it would appear that it was a perfect success; but that engine, perhaps, when set to work, and running down a steep incline (when the engine was supposed to be perfectly free to run down by its own momentum), had actually to be driven down the incline. Of course there was a waste of power, and there was something wrong; therefore a good equilibrium valve, which would reduce the friction, and at the same time not give them something which was worse than the friction, was a great desideratum. The same thing might be said with regard to pistons, of which there were a great many varieties. His (the President's) experience was that, other things being equal, the simplest piston was the best. In locomotive practice either Ramsbottom's or a plain block piston was used with cast-iron rings. A piston had been patented by Messrs. Molyneux and Nichols which he (the President) had tried; it was of the ordinary kind, fitted with a junk ring, and it had valves on each side of the piston, by which the steam was admitted behind the piston rings. When the steam was shut off from the cylinder, it was supposed that there would be very little friction. After a patient trial of that piston, however, he (the President) found that the wear and tear of the valves gave so much trouble as to render it unsuited for practice. It was found with a plain block piston that if the rings were only made sufficiently slack steam might be got underneath it without any injurious leakage, and therefore that gave all that was wanted. As the steam forced the rings out, the piston became self-acting as regarded pressure. Some

engineers put a plain cast-iron ring, $\frac{3}{4}$ths of an inch thick, under those springs; others put a steel spring underneath, so that as the ring wore the spring gave out its strength and forced the ring out. With regard to the lubricators he (the President) had tried several. They were all very ingenious, and some of them worked tolerably well; but the simplest was always the best. That of Mr. Ramsbottom appeared to answer every purpose. It could be regulated to any given consumption, but it required to be properly looked after and adjusted. He had also tried Kessler's, which was on a different principle from Ramsbottom's, which acted strictly by the displacement of the oil caused by the condensation of the steam. Kessler's only acted when the steam was shut off. The steam in the steam chest closed the valves in the lubricator and prevented the passage of oil while the steam was on; but the moment steam was shut off a vacuum was formed in the steam chest, the valves opened and admitted a small quantity of oil. That lubricator acted tolerably well, but the trouble of keeping the valves in perfect order was very great. He had found that the slide valves in ordinary locomotives wore out in eight months when lubricated by the ordinary grease cup; but with constant lubrication, such as any of those lubricators would give, the valves wore from fourteen to twenty months. Amongst other methods that he (the President) had tried for reducing the wear of slide valves was a system of cutting grooves near the outer edges of the valve, but not quite across the valve, so that as the valve passed over the part the grooves were filled with steam, which was carried across the face and so lubricated the surface. He could not say he had found any very great benefit from the system. Another plan was to cut round holes recessed in the surface of the valve for a similar purpose. Again, many engineers, with the view of reducing the friction, made holes and filled them with white metal. He had tried all those things, and he had not derived any benefit from them. With regard to cast-iron slide valves he had tried them, and had had them made of various mixtures of iron, but he could not get them to answer; cast iron invariably cut the faces, whereas gun metal answered perfectly well. His opinion was that oil was a much better lubricant than tallow. The destructive quality of tallow could be especially seen in marine engines: it made the iron quite soft, like black-lead. There was another curious fact which he would mention with regard to rock oil, which he had used to some extent. He had found it to answer perfectly well for the journals and other parts of the engine not exposed to heat, but when that oil was put upon a hot piston rod it would smoke just as if water had been put upon it.

May 2nd, 1870.

WILLIAM ADAMS, PRESIDENT, IN THE CHAIR.

THE PATENT LAWS.

By W. LLOYD WISE.

The unparalleled industrial progress and commercial prosperity of Great Britain are undoubtedly attributable in a large measure to the mental exertions of her engineers, mechanicians, and other scientific men represented by institutions like the Society of Engineers, and therefore it is reasonable that such associations should have a voice in deciding any questions directly or indirectly affecting the interests of the classes they represent. Of these questions one of the most prominent at this moment is that of the Patent Laws, which certain persons now seek to have abolished, notwithstanding that these laws have induced the most important realizations of our greatest inventors, as will be seen on reference to the patent records, which show that nearly every valuable invention has been obtained by the public through the medium of the Patent Office.

It has been suggested to the author that the Society he has the honour of addressing is not an association of inventors; and, in fact, he fears that the term "inventor" has been so hackneyed that it is by many considered rather a derogatory title than otherwise. But he submits that an examination of the list of members of the Society, containing as it does the names of Whitworth, Bessemer, and other well-known inventors, to whose inventive genius this country is not a little indebted for her present position and prosperity, will fully justify his appeal to this meeting for an opinion on the patent question. Moreover, the question is not confined to inventors. The patent laws have done a great deal for good or for evil, therefore every Englishman who has his country's welfare at heart may be said to be interested in the subject. In his paper the author proposes to explain concisely the origin and principles of patents for inventions; then to briefly notice some of the leading objections raised against them; and lastly to offer a few suggestions for improving the present laws, premising that

the importance of the subject renders it deserving of far more elaborate treatment than the limits of a paper will allow him to give it.

From a remote period the sovereign has been considered possessed of full authority to reward persons who, by their researches or travels, and expenditure, brought any new manufacture into existence in this country, and even those parties who now wish to have the system abolished admit that England has derived great benefit from it. Formerly, however, the right of the Crown to grant exclusive privileges by letters patent was sadly abused, particularly in the reigns of Queen Elizabeth and King James I., for we find that when the subject was brought before the House of Commons in Elizabeth's reign, salt, iron, powder, cards, train oil, sea coal, brushes, pots, bottles, and many other branches of trade formed the subjects of monopolies which had been granted to favourites and others to obtain money for replenishing an exhausted treasury. The result was that the House of Commons expressed very strong opinions, and Her Majesty consequently cancelled the monopolies then existing; but as similar abuses were revived by her successor, James I., in his reign, the celebrated statute of monopolies was passed, which enacted that all such grants should be void, and of none effect, excepting grants for the exclusive use of new manufactures for the term of fourteen years, or under, to the true and first inventors thereof, and that the privileges so excepted should be of the same force, and have the same effect as they would have had before the passing of the statute.

Some persons seek to prejudice the public mind against patents for inventions by stigmatizing them as monopolies, but according to Sir Edward Coke a monopoly is "a grant or allowance by the king to any person or persons of the sole buying, selling, making, working, or using of anything whereby any person or persons are sought to be restrained of any freedom or liberty they had before;" whereas grants of letters patent for new and useful inventions do not restrain any persons from any freedom they had before, and consequently such grants are not monopolies.

With reference to the manner in which inventions, properly so called, are made, those who have long been intimate with our most successful and prolific inventors well know that, in by far the greater number of cases, invention results from the fact that a qualified man, having carefully observed the working of some ordinary process or machine, arrives at length at the conclusion that something material is wrong either in the one or the other. It is more than probable, however, that he is in

the first instance struck with these defects without having any definite idea as to the manner in which the evils he detects can be done away with, and it is not perhaps until after months, or it may be years, of study, that he hits upon the idea of which he has so long been mentally in search. Even when he has reached this point, it is more than probable that a considerable amount of time will necessarily be spent in arranging his ideas, and reducing them into that practical form deserving the appellation of "invention." Perhaps the whole object of his thoughts and studies throughout has been the simplification of the process or machine with which he is dealing, and the result in the end is some process or contrivance of beautiful simplicity and perfection, which, on being brought before the public, is at once set down by those who cannot appreciate the travail of often anxious thought gone through by the inventor, as the result of merely a lucky inspiration, or perhaps, to more clearly define their views, "of a fortunate whim." That such thoughts do occasionally flash upon the inventive mind in a sudden and very perfect manner is not to be denied: but that they are not, as a rule, arrived at without long and laborious study might easily be proved. It is, therefore, neither just nor reasonable to expect that men of talent should sacrifice their time and labour, and frequently likewise their health, in attaining objects from which, when arrived at, they were to receive no special benefit.

Reward, then, being evidently necessary to stimulate inventive labour, it is obvious that its amount should be proportioned to the value of the invention as regards the community at large; and the proper body to determine that value is the entire bulk of those who have to avail themselves of the invention. It is upon this principle that the granting of exclusive privileges of limited duration for the encouragement and reward of inventors is based, and the following conditions govern the making of such grants:—

1. The invention must be new, that is to say, it must be something that is not already in public use. It may occasionally happen that another person than the actual patentee has an idea of a similar kind; it may even be that he has a model locked up in his private room, and has made experiments. But crude ideas, and undisclosed experiments, can be of no use to the community, therefore it is for developing the idea, and applying it to the wants of the public, that the man who first obtains practicable results, and comes forward to disclose what he has found out, receives his reward in the shape of an exclusive privilege to make and use it for the term of fourteen years, on the express condition that he shall forthwith faithfully and particu-

larly describe the invention in writing, so that the public will know exactly how to use it for their own benefit when his patent shall have expired.

2. The invention must be useful, otherwise the grant will be illegal, and consequently void.

3. The person to whom the patent is granted must be the first and true inventor, or he must have been the first to introduce the invention into this realm. Hence it will be seen that before any person can legally benefit by a patent privilege, he must have rendered a public service by finding and fully working out and disclosing something never before practically known to the public. Without such a consideration being given on the patentee's part, the grant utterly fails.

The following are among the principal objections that have been urged against the granting of patents:—

1. It has been alleged that there can be no property in ideas. This is scarcely a pertinent objection, because, in order to obtain a valid patent, the grantee must be in possession of something more than a mere "idea." The subject of the grant must, as we have already seen, be a new and useful invention, fully disclosed to the public in a practicable form. Moreover the objection, if tenable as applied to inventions, would apply equally to all other kinds of property, inasmuch as it is only by the laws of the realm that any exclusive property whatever can be created, and the results of a man's intellectual labours are assuredly as fully entitled to that protection as any other class of property, if not even more so, because so long as he chooses to retain the knowledge he possesses, it continues to be his property exclusively, apart from all legal provisions.

2. It has been said that patents are opposed to the principle of free trade, and generally destructive to the interests of trade and commerce. The absurdity of this objection was very clearly shown by Mr. Theodore Aston, the eminent barrister, who, in his paper read to the Manchester Institution [illegible] Engineers, in January last, pointed out that "the patent l[illegible] recognizing property in invention, and making it negot[illegible] the form a patent that can be freely bought and s[illegible] not obst[illegible] but promotes free trade in inventions [illegible] olishi[illegible] patent law, you would not only prev[illegible] but in inventions, for where there is n[illegible] be no trade." Referring to this b[illegible] the objection that patents are [illegible] trade and commerce, Mr. Alf[illegible] some very interesting statistic[illegible] on the 5th of October, 1869, [illegible] branches of manufacture for [illegible]

be found from the export trade returns that there has been a very satisfactory increase, notwithstanding the alleged evil effects of the patent laws.

3. It has been objected that an invention is essentially different from a book or other like creation. This objection has probably been urged rather as a reason why copyright in books, or works of art, should not share the lot of patent rights. It is supported on the theory that no two men ever did write the same book, and that any person may freely use the ideas contained in a book. In like manner it may be safely asserted that two men rarely, if ever, produce inventions precisely alike in all particulars, and that a patented article, like a book, can be freely used after it has been purchased. In both cases the price paid for the article includes its author's reward; but the purchaser of the book cannot print and sell copies of it, any more than the purchaser of the patented article can make and sell precisely similar articles.

4. It is asserted that many persons are simultaneously engaged working in the same track, and that by the granting of a patent to the one who first comes forward with his invention, injustice is done to the others who are running in the race, by shutting them out. This objection is fallacious, because the sooner the public is made acquainted with any useful invention the earlier are substantial advantages realized; therefore the man who first makes a practical disclosure is clearly the most worthy of reward, on the score of public policy. Those shut out, if there be any such, are only in the same category as any commercial man who allows an enterprising competitor to get the best of the market, and if the alleged circumstances do exist to the extent that has been represented, it may be pertinently asked what inducement there can be to all these different persons to b[illegible]ing secretly on a similar object at the same time, but [illegible] of reward to be obtained through the medium of a [illegible] If there be any other reason, those parties who desire [illegible] most simple[illegible] effectual remedy against being shut [illegible] market, [illegible] need only publish their experiments [illegible]p, and [illegible] then not only obtain the credit of [illegible] have [illegible] all likewise put up a most effectual [illegible] one w[illegible] to obtain a patent afterwards, and [illegible] finally [illegible] If they are experimenting with a [illegible] the public, rather than for personal [illegible] y the [illegible] report progress in a public manner? [illegible] of Commons last year that the [illegible] upon the road that they would hit [illegible] they not blocked up by patents. [illegible] from the fact that, in many

manufactures, the difference between success and failure is, seemingly, very small, and that many persons may be exerting themselves simultaneously to achieve what is wanted. This, however, is a strong argument in favour of rewarding the first who succeeds, because the fact of so many persons being engaged with the same object proves its practical importance, but it does not necessarily follow that any of the persons so engaged will accomplish the end in view.

5. It is said to be practically impossible to guard against granting patents for old inventions for which they ought not to be granted; and this objection, although much exaggerated, appears to be about the best founded of all, but it results from the manner in which our patent laws are now administered, and might be in a large measure obviated by suitable provisions, which will be noticed in another part of this paper.

6. It is objected that patents give rise to constant litigation, and that there is great difficulty in contesting invalid patents, but these evils result from defects in our present system of trying patent cases, whereby a vast amount of matter utterly foreign to the actual points at issue is allowed to be imported into the proceedings, causing great waste of most valuable time, rendering a clear understanding of the facts exceedingly difficult, if not impossible, and needlessly increasing the costs to a fearful extent.

Moreover, patent cases are argued before judges who have also to deal with an endless variety of other cases, therefore, although their legal ability is undoubtedly of the highest order, it is not reasonable to expect that they can be fully qualified to grasp all the principles and details of complicated mechanical and chemical questions. Every praise is due to our learned judges for the extensive knowledge, care, and patient attention they bestow in their endeavours to deal with the complicated scientific cases from time to time brought before them, aided as they are in some cases by a dozen jurymen, who probably, in many instances, understand less about the real merits of the case after it has all been gone through than they did on first taking their seats.

The objection to the judges applies also, with some few notable exceptions, to the learned gentlemen by whom patent cases are argued, who not unfrequently take hold of the wrong bull by the horns, and materially assist in getting a case into a regular muddle, so that altogether the trial of a patent case under existing arrangements is in many instances a very slow, tedious, and costly process. These objections, however, are admittedly remediable, and certainly afford no justification for Sir Roundell Palmer's assertion that "everybody knew that

patent litigation had acquired a name of infamy above all other kinds of litigation." He referred to the large amount of time occupied in trying the paraffin-oil case before Vice-Chancellor Stuart, and said, "The reason was that they had to go into the history of discovery at numerous stages, and then all over the country there were hunted up persons who were able to say if they had done anything of the sort before." Referring to the same subject, however, Mr. Newton has said, "We know perfectly well that there is a law in Scotland—whether it is acted on or not I cannot say—which compels parties to a suit to bring the case to such a state that it shall be evident what is to be tried when it gets into the courts." But this is not the case with the patent law. The following is a summary of the whole legal proceedings in the paraffin case, showing, that the course of procedure, and not the patent law, is answerable for the inordinate expenditure of time and money which created the scandal of patent suits.

"Young's patent. Young *v.* White. Before Lord Chief Justice Campbell, June, 1854. Two days.

"Binney *v.* Clydesdale Chemical Company. Court of Session, November, 1860. Hearing of six days' duration. The pleadings in the action extended to upwards of thirty pages of printed matter, and the trial resulted in a verdict for plaintiff.

"First application for a writ of *scire facias* to repeal Young's patent, refused by Sir R. Bethell. Second application for a writ of *scire facias* against Young's patent, refused by Sir W. Atherton.

"Young *v.* Fernie. Application for injunction before Vice-Chancellor Stuart, November, 1862 (Act 25 and 26 Victoria, cap. 42, directs the Court of Chancery to try the validity of patents in suits to restrain infringements). The motion was ordered to stand over until after the trial, the Vice-Chancellor remitting the case to the Common Law Courts.

"Appeal to the Lord Chancellor to cancel this order, and have it tried in Chancery. Application to Vice-Chancellor Stuart to fix day for trial, January 11, 1864. Second application, January 15, 1864.

"Trial of case before Vice-Chancellor Stuart, February 29, 1864; it lasted thirty-three days (without a jury), and terminated in a verdict for the plaintiff.

"Motion by defendants to suspend injunction, pending appeal to the House of Lords, refused.

"Renewed application before the Lords Justices, before whom, by consent, defendants to pay 10,000*l.* on account of costs of the above suit.

"This is an illustration of the way in which the law is administered."

The foregoing statement of Mr. Newton would be a sufficient answer to Sir R. Palmer; but even putting it aside, and reverting to that of the honourable and learned gentleman, the question arises whether there is anything in what he said that is in the slightest degree peculiar to a patent case? Is it not necessary to go into the history of every case, whatever its kind? and do none but patent cases ever occupy as many days, and cost quite as much, if not often more, money than they do? Let us just call to mind one or two of the innumerable cases which might be cited to disprove Sir Roundell Palmer's sweeping charge against patent litigation, premising that the paraffin-oil case referred to by him was one of great public interest, as bearing upon the introduction of a new and important branch of manufacturing and commercial industry, the right of whose originator to corresponding reward was questioned, as not unusually happens in the cases of inventions of great public utility and commercial value; whereas most, if not all, of the notorious cases about to be mentioned had reference simply to the personal interests and petty squabbles of private individuals. Thus the author may instance the Windham case, the costs of which were very heavy; the Yelverton case, with Mrs. Yelverton's constant appeals; the convent case, which occupied much valuable time, cost a large amount of money, and involved the attendance of witnesses from all parts of the country; the case of Lord *v.* Colvin, which is said to have cost something like 80,000*l.*; the undetermined case of Concha *v.* Concha, the costs of which to the present time, the writer has been informed, amount to about 10,000*l.*; and, lastly, the Mortlake case, in which a dispute about 2*l.* odd, after being in Chancery for a couple of years, came before the court a few days since to know who should take some evidence. These are interesting and instructive examples, but, did time permit, it would be easy to cite an endless number of other cases which go to prove the injustice of Sir Roundell Palmer's remarks. He surely must know, as most engineers do, that many arbitration cases about machinery contracts, and other matters totally unconnected with patents, occupy more time than the paraffin-oil case. The fact is, that the present working of many of our laws, as, for example, those relating to ecclesiastical, partnership, contract, and other cases, is notoriously as uncertain and unsatisfactory as the present administration of the patent laws.

7. It is objected that inventors themselves frequently derive the least benefit from their inventions, but it appears to have been forgotten that many men start in business, and fail, and that therefore failure is by no means peculiar to inventors. It should also be recollected that many inventors do succeed in

gaining livelihoods out of their inventions under the patent laws, while others amass large fortunes, as some members of this Society have done; and it may be added that if inventors themselves do not grumble, legislators are not called upon to grumble for them. The complaints justly made by inventors relate to imperfections in the existing laws and regulations, and not to the principle of rewarding by grants of exclusive privileges, which the author believes are generally acknowledged by inventors to be the best means to the end in question.

It may be quite true that an inventor sometimes comes off the worst in his commercial transactions with other persons, so that they are enabled to make more out of his invention than he himself derives from it; but the same rule applies with equal force to many other commercial transactions in which one party gains an advantage over another who does not happen to be quite so wide-awake. Besides, if inventors occasionally fare badly, despite the protection afforded by the patent laws, what would be their position in the absence of any such protection, and what would be the consequence to the public? In order to deal satisfactorily with this question, we must take into consideration the conditions which actually prevail. Thus it must be borne in mind that inventors are seldom good commercial men, and that the mere existence of an invention, however meritorious in itself, does no good either to the public or to the inventor. Nor is it an easy task to convince the public that any new thing is really good; for that purpose it must be taken in hand by an energetic and persevering man with some commercial ability, who must have good reason to expect that reward proportioned to the measure of his success with the public will be legally secured to him, otherwise he will not incur the labour and risk of commercially introducing a novelty. For his security, therefore, and in order that the public may benefit by the invention, protection, such as a patent only can afford, becomes essential. As a rule, manufacturers do not want to make radical changes; innovations involve experiments, alterations to plant, and other expenses, which in themselves do not pay; therefore, while a manufacturer can produce articles that are as saleable as the productions of his competitors, he gains nothing by simply making a change which gives him no advantage over them in the market, so long as they are left at liberty immediately to copy his novel production, and sell against him without any proportionate expenditure of time and capital at starting. Now the man who introduces the invention commercially may be either a manufacturer or one who simply brings about a public demand to which manufacturers are at

length compelled to respond, and in either case the public is clearly benefited by the use of the new invention.

Having thus shown that the inventor often requires the assistance of the commercial man, the next point for consideration is the arrangement between these two parties, the inventor and the commercial man, which in themselves demand patent protection, the inventor himself, as may be gathered from what has been already stated, being in many cases a confiding individual having far more technical knowledge and genius than commercial wisdom, while, on the other hand, the essential qualifications of the man to aid in bringing out the invention are that he should be shrewd, energetic, and persevering. Now, even supposing that without the protection of letters patent such a man could and would convert an invention into a public benefit and a source of profit to himself, is it not obvious that the confiding inventor would frequently be deprived of his just reward by the shrewd man of business did not the State step in, as it now does, to protect the inventor? The author opines, with others who have considered the subject, that such a result would inevitably follow the suggested abolition of patent law, and that, as the natural consequence of such a step, those whose brain is their capital, to whom Great Britain is already largely indebted, and from whom she has so much yet to hope for, would have no alternative but to avail themselves of the encouragement that would be only too readily given by other nations who are now striving to outstrip her in the race of human progression. To illustrate the view here adopted, it may be stated that well-known men have from time to time brought their inventions to this country from Switzerland and other places in which no patent laws exist, and that the want of such protection has been so severely felt in the country named that the passing of a law for protecting mental property is now being powerfully advocated there.

Having, as he believes, shown that it is expedient to protect inventors in the practical application of their mental faculties, the author will now venture to offer a few suggestions for improving the working of the patent system.

In his opinion, the first cost of letters patent should be reduced to the greatest practicable extent; and there should be a preliminary examination as to novelty, but not as to utility; no patent should be sealed out of its order, and the complete specification should be deposited, and abridgments published before the sealing of the patent, so that others may know what the applicant proposes to secure, and if anyone has previously done the same thing in a public manner or has been robbed of the invention by the applicant, and can satisfactorily prove that

such is the case by the corroborative testimony of respectable witnesses, then the patent should not be granted.

When the inventor's pockets are emptied in obtaining his grant, as now frequently happens, he has not the means necessary to afterwards commercially introduce his invention, or even to put it into such a practicable shape as will give him a fair chance of success with the capitalist who might be willing to assist him.

The revenue of the Patent Office might be adjusted so as to make it self-supporting, and in the highest degree efficient, without realizing a large annual surplus as at present, and the bulk of the charges for a patent could be levied say in seven years from its date, when the inventor may be expected to have realized something from his invention.

It is well known that many valuable inventions are made by working men. Mr. Mundella stated in the House of Commons that "during the twenty-five years that he had been an employer he had been connected with upwards of twenty patents, and in every one of them he had a working man as his partner. In fact there was not one in 100 in his neighbourhood the invention of an employer."

But it has been said that poor men and working men cannot bring their inventions into practice for want of capital, and that even if they could do so they would still labour under the disadvantage of being unable to make head against rich infringers who are able to set them at defiance by the costliness of law proceedings; also that the expenses of patenting are too heavy to suit the poor, yet that influential witnesses examined by the Royal Commission on the patent laws showed little or no favour to propositions for reducing the costs because of the tendency that a suitable reduction would have to still further multiply patents. But in the writer's opinion such evidence should not be accepted as being conclusive, because it seems to him that persons of the class denominated "influential witnesses" can, as a rule, well afford to pay the present high charges, and would, therefore, consider it a disadvantage for poor men and working men to be able to compete with them as patentees.

At present, when a poor man or a working man has invented anything new, he is sorely troubled as to the manner in which he shall raise the amount necessary for protecting his invention, and the chances are that, in his distress, he goes to a person belonging to the class called "influential witnesses," who, if fully satisfied that the invention is valuable, probably advances the amount required for patenting, under an arbitrary arrangement by which the poor man or working man gets the worst of the bargain. Under these circumstances, it seems

natural that many such persons will set their faces against cheap patents. But if patents were granted for, say seven years for a nominal sum, and made subject to a payment of 100*l.*, as at present, before the expiration of the seventh year, then inventors with moderate means would stand a fair chance at the outset. It has been asserted that any considerable reduction in cost would give rise to an inconvenient multiplicity of patents, and that more patents than ever would then be obtained for frivolous and useless inventions; but the writer does not think that this objection would be borne out in practice if the proposed reduction in prices were accompanied by a preliminary examination as to the novelty of every invention sought to be patented. The patentee of a frivolous invention, if too poor to work it himself, could not get any capitalist to take it up. The capitalist would prefer something good if he had to pay another person for it. Frivolous patents, the author believes, are generally obtained by persons in trade who have ample means, and can therefore afford to pay the present cost of patenting. It may be laid down as a rule that no frivolous invention would pay for a patent unless largely advertised at an immense outlay, which none but persons possessing considerable means could afford. The exaction of the heavy stamp duty at the end of the seventh year would effectually weed out such frivolous patents as might be producing no commercial results, while, on the other hand, if a patent for a new, though apparently frivolous, invention were of sufficient value to justify the payment of a heavy stamp duty by its owner, there would be *primâ facie* evidence of its having promoted trade in some way. Even admitting that cheap patents might give rise to some abuses, the good accruing to the public would still more than outweigh the evil. The late eminent prolific inventor, Richard Roberts, when giving evidence on the patent laws, as reported on page 40 of Mr. Macfie's book, said :—

"I have a list of something like 100 inventions that I should have patented thirty or forty years ago, but for the cost. I could mention one by which many lives would have been saved if I had had a patent for it.

"I very rarely make models, but I had one made for this. It was made many years ago. I invented it in 1830, and I mean to say, that if it had been put into practice things would not have happened which have happened, and which have caused the loss of many lives as connected with railways."

Evidence of this kind shows that great loss is suffered by the owing to the imposition of heavy taxes upon inventors ek to secure a just reward for their genius.

As an additional argument against cheap patents, it has been asserted that the "Patent Law Amendment Act of 1852," by reducing the cost of patents, greatly increased their number, but in considering whether or not a multiplicity of patents exists so as to cause public inconvenience, only the patents actually in force at any given date should be dealt with. The number of patents actually in force on the 31st of December, 1835, was about 2200. Sixteen years later, that is on the 31st December, 1851, while the cost of patenting remained the same, the number of patents in force was about 5992, or considerably more than double the number in 1835. According to this rate of increase, the number of patents in force on the 31st December, 1867, even had the old heavy charges been retained, would have exceeded 11,984, or double the number in force sixteen years previously, namely, on the 31st December, 1851, while according to the theory of those who oppose cheap patents the number must have been infinitely greater, viewing the fact of the reduction in cost. It is, therefore, rather surprising to find, on reference, that 10,269 was about the total number of patents in force on the 31st December, 1867, being, despite the reduction in cost, a considerably smaller proportionate increase over the number in 1851, than the latter number was over that in 1835, the lapse of time being alike in both cases. So much then for the theoretical arguments against cheap patents.

Respecting the objection that poor men and working men cannot make head against infringers, it may be remarked that, generally speaking, a patent is not infringed until the patentee has succeeded in manifesting the advantages of his invention to the public, thereby creating a demand for it which is felt by producers of inferior manufactures. Then it is that unprincipled persons endeavour to evade the patentee's claims, but by that time his invention has assumed a commercial value which enables him to obtain the assistance of capitalists in maintaining his rights.

Every applicant for letters patent should be compelled in his provisional specification to define in precise language the claim or claims to novelty upon which he intends to rely. This would operate as a check against his afterwards appropriating in his complete specification any part of any invention forming the subject of a subsequent application for letters patent by another person.

All applications for letters patent instead of being referred to the Attorney and Solicitor-General as at present, should be submitted to an acting commissioner, whose official duties should be restricted to the consideration of applications, the

appointment of arbitrators, and the examination of specifications, and who should be assisted by an efficient staff of examiners.

The commissioner, when considering a provisional specification, should have authority to require explanations, as at present, so that he may understand what it is proposed to secure, and he should be empowered to reject the application, if he considers the invention wanting in novelty, of course giving the applicant a clear reference to the prior specification or other publication upon which his rejection is based. The applicant should have the right of appeal to arbitration, the commissioner appointing one arbitrator, and the applicant another, who might be a barrister, patent agent, or other suitable person. The arbitrators should then select an umpire, and the finding of these gentlemen should be submitted by the commissioner to Her Majesty as his final recommendation in the matter of the petition.

Any applicant who neglected to appoint an arbitrator within a given time should be taken to have abandoned his application; whilst in the event of the arbitrators in any case being unable to agree upon an umpire, then one should be nominated by the judges and assessors of a special court which should be appointed for the trial of patent cases, as long since proposed.

By this arrangement the applicant's interests would be fully represented if he took care to appoint a competent person, and the arbitrators, by themselves, would be enabled to thoroughly investigate the documentary evidence forming the basis of the previous rejection, and upon that evidence alone should come to a decision, giving the applicant the benefit of any doubt that might exist in their minds.

But if the provisional specification of an applicant should appear to the commissioner to have been anticipated by a prior unpublished provisional specification, then provisional protection might be allowed to the second applicant, who should at the same time be advised as to the existence of a prior provisional specification that might possibly interfere with his own invention, and recommended to watch the publication of notices to proceed, so that, should the prior applicant proceed, the second applicant would, in case of fraud, be able to oppose, or, if there were no fraud, then to reduce his own claims within the limits that might remain open to him in face of the prior applicant's complete specification.

In the next place, the author proposes that every notice to proceed should be published, and considered in the order of its number, and every complete specification filed at the time of giving notice to proceed, the distinct statement of the claim in the provisional specification being, as already explained, a check

upon the appropriation in the final specification of the invention of any subsequent applicant who may have published it on the faith of his provisional protection. It does not appear advisable that an applicant should be compelled to give notice on a particular day, nor that the time at present allowed for perfecting the invention and specifying should be reduced; therefore notice to proceed with every application might be left at the Patent Office at any time within six calendar months from the date of the petition. Upon the filing of the complete specification the acting commissioner should consider whether it fully describes the invention, and whether it exceeds the ground covered by the provisional specification, and should order such additions to, and modifications in the language of, the specification as may seem expedient, with right of appeal by the applicant to arbitration as before.

Furthermore, it is proposed that woodcuts should be prepared, on a small scale, and somewhat similar in character to the illustrations contained in the American abridgments, and that electrotypes should be furnished with claims, &c., to the leading scientific papers, in which, by arrangement, every notice to proceed, and illustrated claim, should be published in its order. This publication should be additional to a like publication in the *Commissioners of Patents' Journal*, and possibly also in the *London Gazette*.

By this arrangement any person who had been doing the same before, in a practical and public manner, without a patent, would have fair notice, and could avoid future litigation by at once coming forward and proving his case in a simple and inexpensive manner. Cases of opposition might be decided by arbitration, one arbitrator being appointed by each party, and the arbitrators nominating an umpire as before; with final appeal to the Patent Court.

A register, containing the names of barristers, engineers, and other competent persons willing to act as arbitrators, might be kept at the Patent Office, and a proper scale of fees arranged for their remuneration.

Some objections may appear to the satisfactory working of the system here suggested, but the author believes that it will be found to possess some important advantages over most of the systems at present in use. Thus it is proposed to act upon documentary evidence only, and for considering applications on appeal and hearing oppositions, to employ a fairly-constituted and inexpensive tribunal, without complicating the proceedings by the production of oral evidence, or the arguments of counsel or agents for the applicant, he being represented by his counsel or agent, in the tribunal itself, in so far as the granting or

rejection of his application for a patent is concerned. Care is taken, also, to ensure the publication of every invention for the benefit of the public directly the applicant makes even a show of proceeding to the great seal.

The present practice of giving notice to proceed while the invention remains a secret is most unsatisfactory, and renders the system of opposing the grant of letters patent very inefficient, because it is only in cases of fraud, or where the applicant happens to have published his invention, that anybody is in a position to oppose, or has his attention drawn to the subject. In the case of Messrs. Bates and Redgate's application, as reported in *The Times* of 26th May, 1869, those gentlemen applied for letters patent, and lodged a provisional specification on the 2nd October, 1868, and a Mr. Bertie applied for a patent for a similar invention a month afterwards; but as he forthwith gave notice to proceed, and then got the great seal before Bates and Redgate, instead of waiting the full time allowed by law, his claim was allowed to stand against their further progress. Referring to the complaint made on behalf of Bates and Redgate that an inventor would be helpless on Mr. Bertie's contention, the Lord Chancellor said that a second inventor must advertise, and one who had filed the first provisional specification ought to keep a watch over the advertisements, and on observing an invention advertised of an apparently similar character to his own might enter a caveat which would make it incumbent on the Attorney-General to decide which was the prior inventor. This opportunity the petitioner had not availed himself of, and his Lordship could not now protect him from the consequences of his omission by ante-dating his patent. According to this ruling the benefit is practically lost of the four months' time upon which an applicant might otherwise rely for protection while making his experiments to determine whether or not his invention is worth a complete patent, namely, the period from the date of his petition to the latest date at which notice to proceed must be given. In order to follow the Lord Chancellor's ruling, supposing an inventor to have applied on the first of January for a patent for "improvements in the valves of steam engines," then he must either at once give notice to proceed, and forthwith secure the great seal; or, in order to make himself safe, he must oppose every application that may be made for letters patent for improvements in steam engines until he gets his own seal. In fact, it would seem that even if he gets his grant sealed promptly, he may have to oppose every application under a similar title for some time after, to prevent another patent being granted with a date prior to his own. This, on the face of it, is a most unfair proposition, hence the

foregoing suggestion that no notice of intention to proceed should be allowed to take effect out of its regular course with respect to the dates of other petitions for letters patent. The Lord Chancellor's ruling in Bates and Redgate's case appears to have been based upon the assumption that he who is the first to come forward and ask for the great seal is the one whose invention is in the most advanced stage, and consequently the one from whom the public has the most to expect; whereas the author thinks that the evidence afforded is rather that of mere pecuniary ability on the part of the inventor.

The author has heard it suggested that until the first of two petitioners for letters patent has applied for his seal, there is no means of knowing whether or not he intends to proceed and bring his invention to perfection, and that consequently there is no good ground for refusing the great seal to the second petitioner, if he is the first who asks for it, even to the exclusion of the prior petitioner, because by such a refusal the public might, in some cases, be kept from the knowledge of an invention during a longer period than would otherwise be the case. Now this theory seems to pre-suppose two things, namely: First, that the sealing of the patent is a guarantee for the fulfilment of its provisions by the filing of a full description of the nature of the invention and the manner of performing it; and secondly, that such description will be prepared and filed and laid open for the information of the public at an earlier date than would be the case if the grant of letters patent to the second petitioner were withheld until the time allowed for proceeding upon the prayer of the first petition had expired. As actual facts clearly show both of these suppositions to be erroneous, it is difficult to conceive any just ground for adopting the theory advanced in Bates and Redgate's case, which points clearly to the urgent need that exists of some amendment in the present practice in reference to the sealing of letters patent. While the sealing of a patent before the expiration of the full time allowed for proceeding is a very common practice, it nevertheless rarely happens that an inventor after having obtained the great seal files his final specification until on or about the latest date at which the law compels him to do so to save his patent, and furthermore it so happens that a number of patents actually sealed become void by reason of the grantee's neglect to file complete specifications, and that consequently the public is never any better off for information in respect of the inventions for which those patents are granted than it would be were the patents never sealed at all.

The foregoing suggestions, if carried out in conjunction with more complete indexes and records at the Patent Office,

official reports of all cases tried in the Patent Court, the granting of special titles as "Counsel of the Patent Court" to any barristers who might pass an appropriate technical examination by a competent authority (without, however, restricting the right of other barristers to practise in the Patent Court), more accurate definition of the various issues to be tried in every patent case, and an official registration of all patent agents, would, the writer believes, be found to obviate those evils which patentees and the public have just cause to complain of in the present working of the patent laws.

The author has not ventured to comment upon the proposal which has been made to set apart 200,000*l.* or more annually for rewarding all meritorious inventors, that proposition being on the face of it too absurd and impracticable to merit discussion. His main object has been to show that a few simple amendments will enable the community to realize all the advantages of the present patent laws without suffering their attendant evils.

DISCUSSION.

Mr. Olrick said that the patent laws were undoubtedly very defective, and the question was whether they should be retained as they were, or be abolished. He thought there was a middle course, and that was to improve them. One of the reasons advanced in favour of the abolition of the patent laws was that they were an obstruction, which he denied, and for the reason that whenever any successful patent was worked out, there always followed in the wake of the patentee a number of imitators. Some of the imitators might develop useful improvements upon the invention, so that the law was not obstructive, but encouraging. Again, it was said that the patent laws led to a monopoly, but that the author of the paper had disproved. The next objection urged against the patent laws was that they were opposed to the principle of free trade. To answer that objection he would refer to a paper on the patent laws by Mr. Theodore Aston. From that paper it appeared that in 1866 there were 596 licences granted and assignments made to other proprietors; in 1867, 606; in 1868, 653; in 1869 there were 675, and those were years when trade was very dull. But when it was stated that some of those assignments cost 100,000*l.*, the case was much stronger. Therefore those who asserted that the patent laws were opposed to the principle of free trade forgot that the number of patents represented millions of pounds sterling. If persons could afford to pay such high sums for patents, there must be some return for the investment, and if they were not protected, no one would invest their money in

inventions. Mr. Macfie objected to the patent laws, but he was obliged to admit to the Parliamentary Committee that although 400 patents affecting his trade of a sugar refiner were in existence, he suffered no impediment, no interruption, no inconvenience in any way to his business, but he said he might. He (Mr. Olrick) did not consider that the patent laws were so faulty that they ought to be abolished. Mr. Macfie said that patent property at the present day had no legal right or claim to recognition, but a man's experience, his brain, his talent, his ingenuity, had a perfect right to be appreciated. And it could be appreciated in no better way than by being paid for at its proper value, and protected by a patent. Again, it often took a great deal of time and labour, and involved a large expenditure of money, to work out an invention. That was capital invested, and ought to be protected in the same manner as any other invested capital. There was another right besides patent right that had been clearly and distinctly proved and protected, that was copyright, which was the protection of books and works of art, and works of the brain. Nearly all the arguments that had been brought forward in favour of copyright could also be used in favour of patents. Hence if the one was worthy of protection and remuneration, certainly the other deserved the same. In countries where there was no protection, inventors left their homes and went to England and other countries where they could be properly protected, and where they could get a return for time and capital invested. If there were no patent laws nor protection by patents, the consequence would be the existence of a system of secrecy which must be deprecated, as it would lead to distrust and be a fruitful source of much evil. The author had proposed in his paper a number of alterations, and on the whole he (Mr. Olrick) agreed with them. There were some details as to the first examination which would prove expensive. At present a patent could be obtained in six months for about 40*l.* or 50*l.*, but if an inventor was to go to the additional expense of 40*l.* or 50*l.*, it would be rather too expensive. At the present time there was a surplus of about 40,000*l.* a year from the Patent Office. Let that money be spent in appointing men capable of examining patents, and let the specifications of inventions be examined before the patent was granted, but when it had been examined and found good it ought to stand in law. He further held that if a patent was granted and was afterwards challenged, the Government ought to defend it, and not the inventor. There were some abuses which he thought it right to notice. Some years ago a patentee successfully opposed the patent of another person who was infringing his. The Attorney-General refused the com-

pletion of the patent, but two days after the other patentee obtained a new provisional protection for precisely the same thing, and the Attorney-General granted the patent and signed them both. That showed there was not a proper examination, or it would have been impossible for the same man, after four or five days, to grant a patent for identically the same thing. Further, it should be penal for a patent agent to take out a second patent for the same thing for a second person within a few days or even weeks of a previous patent for another person. The trial of patent cases by juries ought to be abolished, as pointed out by the author of the paper, and they ought to be replaced by a judge for the special purpose, and if there was any appeal it ought to be decided by eminent judges, and not by juries. No doubt at the present time the expense of the trial was much too great, and the consequence was that as a great many patents were taken out by poor mechanics, they often lost them because they were unable to contend against moneyed parties in an action at law. He (Mr. Olrick) differed from the author of the paper with regard to payments, which should not be made as at present, but in a similar manner to the plan adopted in France. There it was paid at the rate of 5*l.* a year, and that amount anyone could continue to pay, but when it came to 50*l.* or 100*l.* at a time it often became very difficult, and many a good patent was lost through those heavy sums having to be paid down at once. With regard to the time, he (Mr. Olrick) proposed to continue the patent for twenty-one years instead of fourteen. Certainly there was no need for the abolition of the patent laws, every argument told flatly against such a course.

Mr. Galloway said that inventors and inventions had formed the basis of England's wealth and greatness, and just in proportion as any country encouraged and supported genius and developed practical science, in the same proportion had it been enriched, and in proportion as any country had neglected so to encourage it, in the same proportion had that country retrograded. If that was so, it was of the highest possible importance that the law which gave protection to inventors should be well guarded, and that patentees should have their interests specially cared for. An anomaly at present existed with respect to the protective laws, inasmuch as there was one law for trade marks, another law for copyrights, and another application of the law for what were termed patent rights. The three should be based upon one principle of law, and then some of the injustice which was at present felt would be removed. The remedy which he (Mr. Galloway) proposed was that by a vote of Government the surplus money which had accumulated over and above the

expenses connected with the Patent Office should form the nucleus of a fund to which members of the British Association who felt an interest in practical science should contribute, and that fund should be under the management and control of certain members of the British Association, of the Society of Engineers, of the Institute of Naval Architects, and of the Society of Arts. With a fund like that properly applied the interests of inventors would be promoted, and invention stimulated.

Captain SELWYN, R.N., said that the patent law question had arrived at a stage which required that every effort should be devoted, not so much to ascertaining what might be the form which amendment might take, as to combating the theories and vague generalities which were constantly propounded, and that not by men occupying positions of little influence, but by members of Parliament and others. The abolition of the patent laws was altogether out of the question, for patented inventions enabled England to hold her position among the nations, and to propose to go back to that state in which invention was before the granting of any protection for invention, was only to retrograde to a state of barbarism, from which they would gradually fall out of mental culture altogether. No inventor would ever think of giving the public the sole benefit of many years of anxious labour and expenditure of capital. Those members of the House who wished to abolish the patent laws had admitted that invention was deserving of some reward, and the only thing which seemed to strike the manufacturers in the House was that that reward should be given by the State and not by themselves. They desired that inventors should have inducements to make improvements in their manufacture, but not that they should have to pay for those improvements themselves. With regard to frivolous inventions he (Capt. Selwyn) would like to know what was a frivolous invention. It could not be characterized as frivolous if it could be used, and used profitably; therefore all objections to such inventions as those fell through; but inventions that were really frivolous did not cost anyone anything except those who amused themselves with them. He did not think with regard to arbitration that any arrangement by which matters should pass into the hands of one person could possibly be satisfactory, considering the multifarious subjects which fell under the head of patents and inventions. His proposition was to have indefeasible patents in the same terms as indefeasible titles to other property. Directly an inventor applied for a patent his claim should be published, and he should have provisional protection during the time he was working his invention out. When he desired to perfect his

patent, let it be published and remain public for a limited time. During that time if no one claimed a previous right, and if there was no previous patent for a similar thing, then let it be from that time forward for fourteen or twenty-one years indefeasible. That would sweep away all the difficulties attending arbitration. The only instance in which relief should be given to previous users should be to a person who might, even after the issue of the indefeasible patent, satisfactorily prove that he had been a user for years previously, when he should not pay any royalty; but the general public should not have any such right, as the user had not published it to the public. It was to the true interest of the country to retain the patent laws, but in a modified form.

Mr. CAMPIN, as a lawyer, supported the proposition to have indefeasible patents. He also considered a jury the worst possible tribunal for a patent case, and advocated the appointment of a judge assisted by a scientific assessor. The suggestion for reducing the cost of the provisional was a very excellent one, and that of a small annual payment was also very valuable.

Upon the adjournment of the discussion to the next meeting, Mr. Olrick gave notice of his intention to bring forward a resolution in support of a continuation of the patent laws, subject to suitable amendments.

June 13*th*, 1870.

WILLIAM ADAMS, PRESIDENT, IN THE CHAIR.

THE PATENT LAWS.

ADJOURNED DISCUSSION.

Mr. WEBSTER, Q.C., said he thought that no one would have the hardihood to assert that an inventor who used his brains in the production of a piece of machinery was not as much entitled to a property in his production as a man who brought out a new song or similar trifling matter. But the question could not be dealt with in that manner; the world owed a large debt of gratitude to inventors; and when it was said that the patent laws had better be abolished because they were injurious to inventors, and that they did not reap any reward from them, that was but saying that there was a mass of people who occupied a very high position as regarded brains and intellect who were willing to devote their labours to the public, and yet were not rewarded. That was a necessary corollary to the objections made in a philanthropic spirit by those who said it would be better for inventors themselves if there were no patent laws. If that was so, it was only to say that a man would apply his brains to produce those inventions which had been the glory of the country without reward. No one could suppose that those inventions would have been developed but for the hope of reward, and for the property which the law gave in those things. He did not know any—except some wild revolutionary spirits who had had no practical experience—who said inventions were not to be rewarded, and that there was not to be property in brain work. What they said was that the present form of the law was bad. He would not say it was a good form of reward, because he had for more than a quarter of a century on every occasion advocated a substantial alteration in the patent laws. In discussing the present question, the first consideration was, was it right that there should be property in inventions,—property in brains applied to inventions? He assumed that all present were of opinion that there ought to be a property in inventions, or rather that inventors ought to be rewarded. Having conceded that point, he (Mr. Webster) conceived that inventors could not

be better rewarded than by giving them a property in that which they had created. If the law gave them property in a song, in a book, in a novel, or in a frivolous piece of music, ought they not to have a property in improvements in a steam engine, in the electric telegraph, or in any similar invention? A man who had made an invention had created a sort of property which was as much a creation as anything could be. It was said that inventors could not help inventing, and thus laws were not needed for their protection; but inventions cost money to perfect them, and they would of course be used or copied by others if they were not protected. Inventors therefore ought to have a property in their inventions, and they could not be better rewarded than by giving protection to those inventions under some system like the present. And although he (Mr. Webster) protested against the present system of creating that property, yet if there was to be a property, attention should be directed to the way in which that property was to be created and protected, and time should not be wasted in profitless discussions as to whether there should be a patent law or not.

Mr. R. A. Macfie, M.P., observed that in Mr. Wise's paper he found the following statement:—"The patent law, by recognizing property in invention, and making it negotiable in the form of a patent that can be freely bought or sold, does not obstruct, but promotes free trade in inventions." He (Mr. Macfie) did not think that Mr. Aston's statement, as there quoted, was quite correct; the patent law did not recognize property in invention. It constituted property in invention, perhaps, if it could be said that it constituted property when it only gave privileges for fourteen years. Anything that was called property was that which could be held for ever, transferred from hand to hand, and from generation to generation. Certainly Mr. Aston was right in the second part of his statement, that without something of the nature of property they could not have trade. He spoke of free trade, and as he expressed himself he spoke correctly—free trade in inventions; but he (Mr. Macfie) held that the patenting of inventions was opposed to free trade—as generally understood—free trade in the walks of commerce. He believed it was inconsistent with free trade in two ways. In the first place free trade meant free interest, and there could not be freedom in manufactured articles unless there was also freedom in their manufacture. The very object of the patent laws was to retard the freedom of their manufacture, and thereby prevent freedom of trade for fourteen years. The a[illegible] of patent laws said that free trade was a good thin[illegible] owledge of invention was better; they were willin[illegible] omise freedom of trade for a few years in

order to obtain the greater advantage. The second point in which the granting of a patent was inconsistent with free trade was that British manufacturers were in an entirely different position from that which they occupied before the inauguration of free trade. Formerly there was no such thing as importation of foreign manufactures except under the burden of very considerable differential duties. Those duties were so large that if the foreign manufacturer was exempt from a number of royalties and restrictions to which the British manufacturer was subject, the loss to the rival at home was not very serious, because the injury done by subjecting him to royalties at home, when his competitors abroad paid no royalty, was less than the benefit accorded to him—the protection afforded to him by the financial system which prevailed at home in those days. But since free trade had been completely established, and since there was no protection reserved for British manufacturers, it was quite plain that an injury was done to them—that free trade was not existing—if by the patent laws the British manufacturers were subject to duties to which their rivals were not. The end of the paragraph to which he had alluded ran thus:—"Mr. A. V. Newton submitted some very interesting statistics at the Social Science Congress on the 5th October, 1869, showing that taking in all the branches of manufacture for which England was celebrated, it would be found from the export trade returns that there had been a very satisfactory increase, notwithstanding the alleged evil effects of the patent laws." He (Mr. Macfie) heard that statement, and was present at the discussion that then took place. The whole Continent was now running the race of commerce with them, and if they were to be amongst the foremost, they must be able to compete with foreign manufacturers on equal terms. But that was not so, if the British manufacturer was subject to restrictions or exclusions for fourteen years, or at the best heavy royalties, while their rivals could compete with them not only in the markets of the world, but in our own markets, without subjection to those heavy burdens. Mr. Wise in his paper made a comparison between a book and a patented article, and that idea was brought forward by Mr. Webster, but he (Mr. Macfie) did not consider the comparison was a good one; he differed from Mr. Webster upon his ideas of property. In the last paragraph but one of his paper Mr. Wise said that he "has not ventured to comment upon the proposal which has been made to set apart 200,000*l.* or more annually for rewarding all meritorious inventors, that proposition being on the face of it too absurd and impracticable to merit discussion." He (Mr. Macfie) was the author of that proposition, and he would ask wherein lay its impracticability.

He considered it to be quite practical, although not quite conformable to the ideas of those who had very exalted notions as to what should be the reward of inventors. There were two classes of inventors—those who presented their inventions to the world, and those who sought to make money out of them. It was very well for a man to obtain a monopoly, but the Government should not allow it. At the same time a poor man should be rewarded for a valuable invention, and that reward should be granted by the State; that reward might consist of money obtained by means of taxes, whilst in other cases—those of the less needy—the reward might be some honorary recognition—a title, a medal, a letter of thanks from the Queen, and such like; but the application for monetary reward would become the exception. The proposal to grant compulsory licences was similar in principle to his (Mr. Macfie's) suggestion, which, if carried out, would do away with the formidable difficulties encountered by manufacturers, and by which they were debarred for fourteen years from the inventions, and were made for that period competitors and rivals with others. There appeared to him (Mr. Macfie) to be no reason why a world-wide system of rewards should not be adopted, and that every country should contribute to a fund for rewarding inventors of all nations, all nations being mutually benefited by the results of inventions. According to the present system, the original inventor got a small part of the reward, and the man who tried it in his factory got a small part, but the great bulk of the profit went to the capitalist who helped to bring the invention forward. The disadvantage of the present system was that the bulk of the property was given to third persons, who were mere speculators or persons who hap-hazard fell into good luck: that certainly should not be, although it was the necessity of the present case.

Mr. Spencer took objection to a court of examiners as proposed in the paper, and which he considered very undesirable. He was of opinion that the question of finding out utility and novelty should devolve upon the patentee. No court of examiners could be expected to comprehend the minutiæ of, for instance, lace machinery, which required a lifetime to understand. A court of examiners had proved a failure in Prussia, and wherever else it had been tried. In America he (Mr. Spencer) had applied for patents and they were refused for the most frivolous reasons. He considered a court of examiners as thoroughly impracticable. With regard to the proposal to reduce the fees, he did not think there was much objection to that. It might be desirable to make the fee 25*l.*, payable in five years. He also agreed with Mr. Wise that the

provisional specification might be made public. He (Mr. Spencer) did not by any means agree with the system of rewards proposed by Mr. Macfie, whose arguments were those of the manufacturer. Without doubt inventors would much rather have a substantive reward for their ingenuity and labour than a mere medal or a certificate of merit. He did not fear the abolition of the patent laws, as the common sense of the country would support the right of the inventor. Mr. Macfie referred in his pamphlet to the working of inventions secretly in place of patenting them; but in such case the inventor alone would be benefited, and not the country. Krupp worked his invention for fifteen years without a patent, but if he had gone to the Prussian government and shown them his method of working, it would have been published. He, however, worked his invention for fifteen years, and in the meantime the world had no knowledge of what he was doing. If his specification and process had been published it would have been of great benefit to the steel trade, and if it had not been for Bessemer the trade might still be to a great extent in Krupp's hands. Mr. Bessemer, however, acted differently, and steel that was sold at 40*l.* per ton was now down to 15*l.* or 16*l.* If therefore manufactures should be carried on in secret, it would not be to the benefit, but greatly to the loss, of any country. It might be a nuisance to manufacturers to have patents coming continually in their way, but it was of great advantage to the country.

Mr. Imray said that for the last few years he had been engaged with others in framing a bill for the improvement of the patent laws. In arguing with Mr. Macfie the great difficulty was that they were speaking in different terms. Mr. Macfie had not the same ideas of property that he (Mr. Imray) had, nor had he the same idea touching the rights of inventors. Mr. Macfie considered that the only property was that which a man might keep for ever. But was not the lease of a warehouse whose site was valuable for some building a property, though it might only be for fourteen years? In the same way a poor inventor obtained protection for fourteen years, and although the period was limited, the invention was just as much his property for fourteen years as the house which might be held on a lease. He could not agree with Mr. Macfie in his notions about free trade. He confused his ideas between freedom of trade and free trade which approached to appropriating the property of others. Mr. Macfie argued that because a man had a protection for fourteen years, thereby the freedom of trade in the invention was stopped. That was wrong, for if a man had a protection for fourteen years for something new, the world was bound to use that something. It was something addi-

tional to what was before. But real restriction upon commerce was to restrict something that was known, and that was used before. When the corn laws existed the whole world required bread. Corn was a thing, too, that was grown, a thing supplied, and it was very wrong to put restrictions upon it, because it was a necessary of existence common to all the world. But when Watt invented the steam engine, it was a new thing; the world had not had it before. It was only because it was a better thing and a more useful thing that the world took to it, and they took to it because instead of paying more they paid less. The effect of every invention if it succeeded was not to defraud the public of money, but to bring more money to the public, so that instead of being a restriction upon trade a patent for an invention was really an encouragement to trade and a promotion of industry. Mr. Macfie's proposition was that there should be a certain set of rewards to be provided for inventors. In the first place, who was to settle those rewards? If Mr. Macfie could show how any tribunal could be selected which could settle that question of rewards, then he would get over an enormous difficulty. As to honorary distinctions, there was no honour nor any title or certificate that was at all equal to the honour that an inventor got under the present system. It was absurd to talk about conferring honours upon inventors; if men did invent they had honour; they achieved it. From an extended intercourse with the working classes he (Mr. Imray) found that the predominant and unanimous sentiment amongst working men, whose interests Mr. Macfie said he represented, was to have better patent laws, not to have an abolition of them. They wanted patents cheaper, and to be made more certain, and they also wanted that when they had obtained a patent it should be theirs as much as a man's house and field were his own. Those were the sentiments of the working classes, and amongst inventors of a higher class the sentiments were just the same. Unquestionably the patent laws required amendment, but no rational man would advocate their abolition because in some points they were objectionable.

Mr. Campin said that Mr. Macfie's proposition was defective inasmuch as the patent laws, by means of granting or making a property which might be transferred from one to the other, induced manufacturers to practically work out inventions, and the question was whether inventions were practically developed for the service of the community, and although the Government might reward even on a higher scale by means of money, by medals, and by certificates, &c., the inventor would fail to see an inducement in that, and there would be no inducement to anybody else to labour for the bringing of the invention to

practical perfection and introducing it to the service of the community. The difficulties of effecting that were great, and without a property being created which would reward those who introduced improvements as participators in it, the community would gain no benefit by any means of reward, and no benefit by inventions being recorded at the Patent Office.

Mr. MURDOCH said that the great evil of the present system was the expense of litigation. He did not attach much importance to what was called the system of cheap patents, because he thought they might often lead to more expense in litigation than would be saved in the grant of the patent. He would submit that efforts should be directed to the question of rendering patent property, when it had received nominal protection from the Crown, properly secure in the law courts of the country. At present the expense of an action was so great that an inventor, although he might have a patent right, was practically shut out from asserting that right.

Mr. WEBSTER said that Mr. Macfie's notion about world-wide patent law and world-wide reward was perfect romance, and the observations of the same gentleman respecting free trade were an abuse of the term. Patents created the trade, and there was no trade, properly speaking, with which they interfered. The notion of obstructive patents was a fallacy, and there really was no such thing as a monopoly in an invention which often required years to work out to a successful issue. Everyone was a monopolist who had anything to lose, and when Mr. Macfie talked about a patent being a monopoly, he (Mr. Webster) would reply that a patent was nothing, so to speak, but a lease or easement for a certain time, like an easement of a piece of land. What was wanted was a feasible and practical means whereby every man who made an invention could be assisted afterwards and be protected in what had been done before. He had never advocated a system of examination, but a great deal might and ought to be done to make an inventor acquainted with what had been done before, and although examiners might report against an invention, the inventor ought to insist upon having his patent, because there were many cases in which an inventor was so far in advance of his invention that there was no man competent to judge, and it would be monstrous to say he should not have the property he had created. And then, as to the inventor's fund. How was that to be distributed after the patent had succeeded? As for honours, titles, and medals, no man who wanted bread and cheese would care for them; the invention was his property and he had a right to be compensated if he parted with his interest in it for the benefit of his fellow-creatures.

Mr. MACFIE wished to ask two questions. The first was, whether legally and technically it was not correct to speak of patents as a monopoly; and, secondly, whether a decision was not lately given which constituted the possession of a patent a real monopoly? The decision was that whereas formerly it was held that an article made according to a patent process might be sold, now, he believed, if anyone could identify or trace in the manufactured article the machine by which it had been made, it was illegal to sell it in this country. If that was so, there could be very little doubt with regard to the first that it was really monopoly.

Mr. WEBSTER said there could be no doubt that a machine made abroad, or an article made abroad by a machine patented in this country might be restrained, but with regard to monopolies, they were odious where they restrained an existing trade; but a patent created a new trade, and it was an abuse of the term "monopoly" to apply it in such cases. As regarded a machine made abroad it was a great hardship, and the law ought to be altered with regard to that point. That was one of the small matters of detail causing inconvenience to the public.

Mr. LAWSON (of the Chancery Bar) observed that the author had suggested that in granting patents originally there should be a preliminary examination before an examiner, and that the inventor should have an appeal from that functionary to a court of arbitration. It appeared to him that the suggestion Mr. Wise had made was not feasible, because of all courts for creating expense, a court of arbitration was the most effective. If that was avoided by the suggestion Mr. Wise appeared to advocate, that certain lawyers, engineers, and others should devote themselves specially to the matter, then came the difficulty that the inventor appealed from the commissioner, who was an officer of State, and therefore a responsible officer, to a body of gentlemen who were irresponsible, and that was a matter to which it would be quite impossible to obtain the sanction of Parliament. With regard to the best way in which litigation might be prevented, he (Mr. Lawson) would direct attention to the Indian Patent Law, which embodied a principle that prevented litigation to a great extent. That principle was that after a certain preliminary examination had been made, if the patent was granted at all, some credit was given by the law to the patentee as holding a valid patent. Therefore, when an inventor in India had a patent and brought an action against an infringer, it was no d[illegible]o that action to say that the patent was not new, tha[illegible]ification was bad, and that the man was not the true in[illegible]ess the defendant could say he himself invented it. T[illegible]pear to be an easy mode of calling upon a patentee

to show cause why his patent should not be declared void upon any of those grounds, and instead of the cumbrous and expensive method of proceeding adopted in this country, much easier and cheaper means were adopted in India to enable the public to call upon the patentee to support his patent. The result of that was that since an infringer could not successfully defend an action by a patentee simply upon the ground of defect in the specification, he did not infringe a patent in the expectation that a hole might be found in the specification. If he had good grounds for believing that the specification was bad, then the patentee was called upon to show to the contrary. At the same time the Court had the power of amending the specification, and therefore if the objection was frivolous the person who made the objection suffered. Another point he (Mr. Lawson) would suggest was that in any reform which might be introduced in the patent laws, trial by jury should be abolished, because, although a jury was a most valuable tribunal in all matters relating to the liberty of the subject, it was of all tribunals the very worst for discussing technical points or coming to conclusions on the merits of rival patents. It would be much more satisfactory that a judge well informed, and aided by an assessor, should have the trial of such cases. Another point to which he (Mr. Lawson) would direct attention was what was called "disclaiming an invention." Assuming it was right that a patent should be allowed to be the subject of disclaimer, there was not the least doubt that there should be an appeal allowed in the case of disclaimers as in all other cases. At the present time an inventor went before the law officer, who might have particular views upon the question, but when once he had refused his fiat, that fiat was final.

Mr. Wynne said that Mr. Lawson had promulgated a notion which ought to be denounced, and that was that cases should be tried without juries. The very condition that society should insist upon was that the Court of Chancery should be relieved from all jurisdiction in reference to letters patent, unless it tried causes with the assistance of a jury. It had in its wisdom decided that it was more competent to try patent causes without juries than with them, but anything more absurd and unreasonable than the decisions of the Court of Chancery in patent cases it was impossible to imagine. The value which inventors attach to Chancery proceedings was shown by the fact that few cases had been tried in the Court of Chancery as compared with the number that had been tried before Courts of Common Law in which juries had been employed. The Court of Chancery ought to be deprived of all jurisdiction in reference to the patent laws.

Mr. Wise, in replying to the discussion, said that as it was already past the regular hour for closing the meeting, it would be utterly impossible for him to deal with the remarks of all the able authorities who had spoken. He must therefore limit his observations to one or two leading points that had been raised. With regard to his (Mr. Wise's) suggestion to submit applications to arbitration, he had stated in his paper that the suggestion might be open to objection. At the same time, he thought it might fairly be tried, as there was no particularly expensive element in what he proposed. Arbitrations, as generally understood, involved an array of talent and heavy expenses on both sides, but that was not what he suggested. He did not propose that the arbitrators should go into the history of inventions, but to have a board of examiners who found certain records of what had been done before, and they having, on the ground of matter contained in those records, recommended the refusal of an application, that matter should be compared by the arbitrators with the documents sent in by the applicant. He (Mr. Wise) believed Mr. Olrick was in error in assuming that the proposed examination would entail on the patentee an additional outlay of 40*l.* or 50*l.* The examination would be made by Government officials, paid out of the fund derived from patentees, and the only questions referred to arbitration would have reference to the similarity of the matters described in any two or more specifications. The arbitrator selected by the acting commissioner would be paid out of the patent fund, whilst the patentee would no doubt in most cases appoint his own patent agent, so that a disputed point could be quietly argued in a private way, and generally settled in an hour or two. Any little additional expense incurred over the present system would be more than compensated by the additional security the patentee would derive, and if there was a serious flaw in his claim, it would be far better for him to know it at once instead of discovering it after devoting much time and money to the working out and introducing of the invention. Mr. Olrick's suggestion, that the Government should defend patents, was very objectionable. It would be considered an unwarrantable interference and an undue oppression. Once admit the principle that Government should defend one kind of property, the application of that principle to all kinds followed, and the impracticability of that was apparent. Mr. Olrick also referred to the fact that sometimes protection was obt[illegible]y a second party for an invention already protected [illegible]uggestion he (Mr. Wise) made removed that objec[illegible]eals on points of law were decided by judges and [illegible]ies; juries only dealt with questions of fact. He [illegible] with annual payments, because they caused

an immense amount of trouble and anxiety, and great risk. With regard to the suggestion that there should be indefeasible patents, he did not think that would be practicable. It was proposed to except from the operation of those patents any persons who had used the same thing before. But it appeared to him that if once a man's right to use a patented invention was admitted, his right to sell was also admitted, and by admitting his right to sell the right of his customers to buy was admitted, as also their right to use; and thus the patentee would be outsold, as the prior user and his customers had no royalty to pay. The speech of the honourable member for Leith (Mr. Macfie) had been so thoroughly met in the course of the discussion, that he (Mr. Wise) considered it needless to occupy the time of the meeting with any further observations on that branch of the subject. With reference to what Mr. Spencer had said, he (Mr. Wise) wished it to be particularly understood that he did not advocate the objectionable system of so-called preliminary examination adopted in Prussia, observing that he had found the principle generally laid down by those who knew the working of the laws in that country to be, that if the invention was good the patent was refused, and the inventor afterwards found his invention extensively used there. He (Mr. Wise) could not agree with Mr. Lawson's views based upon the Indian patent law which he thought made matters worse instead of better. Thus it was unfair that a man should be debarred from using an invention improperly secured to another, without first being put to expense in proving the invalidity of the patent. On the other hand, he considered it objectionable to give too many facilities for attacking a patent, as such a course only offered strong inducements to persons in trade to combine for the purpose of harassing and depriving a patentee of his rights directly the value of his invention became apparent, and the patentee was then compelled to incur expense in supporting his patent, or if unable to do so must suffer the consequences, whereas, justice seemed to demand that the patentee should be the first person to take proceedings, saving in very special cases. In conclusion, as respected Mr. Wynne's remarks, he (Mr. Wise) thought that a special court with assessors would remove many of the objections raised by that gentleman with reference to the Court of Chancery.

Mr. Olrick then rose to move a resolution in favour of the patent laws, of which he gave notice at the previous meeting. He considered it to be the duty of the Society of Engineers, which included so many members interested in the maintenance of property under the patent laws, to express their conviction on the subject. He therefore proposed the following resolution:—"That in the opinion of this meeting the

granting of exclusive privileges of limited duration for the encouragement and reward of inventors tends largely to promote the industrial progress and commercial prosperity of Great Britain; and further, that the abuses which attend the present patent system as now administered are capable of removal by suitable amendments in the laws, and that therefore all practicable means should be adopted for attaining this important object."

Mr. E. FIELD seconded the motion, which was carried unanimously.

The PRESIDENT expressed the obligation which the Society of Engineers was under to the author of the paper, and to the eminent gentlemen who had attended the meeting, and had unreservedly given their views on the subject under discussion. Mr. Macfie held opinions directly opposed to those of most, if not of all, patentees, but it was important that opposite views on all such subjects should be heard in a discussion like the present, which had been very interesting.

The following letters from members who were prevented taking part in the discussion were read at the meeting:—

DEAR SIR, JUNE 12, 1870.

Being unable to attend the adjourned discussion on Mr. Wise's paper, I will offer a few remarks on this highly important subject in writing.

I perfectly agree with the whole of the paper, for if anything needs reforming it is certainly the law and practice of patents. The grievances of inventors, especially of the poorer ones, are so great that the subject ought to be introduced in Parliament as soon as possible; and I see no reason why a Society like ours should not use all the interest and influence it possesses to further this object.

According to my own experience and that of other patent agents with whom I have frequently discussed these matters, I think the following points, in addition to what has been proposed in the paper, ought to be particularly attended to in any future legislation. I may observe that my remarks are the result of actual experience and mature consideration. I shall not allude to the questions of legal proceedings, because Mr. Wise has so ably discussed them in his paper.

First, as to the practice of granting provisional protection by filing a provisional specification. Although it is objectionable in several respects, and especially because of the undue latitude it allows in the final specification, still the system is so universally liked by inventors themselves, that it should be retained if

means could be devised for remedying its worst defects. The principal means must, I think, be a strict examination of the final specification by a competent body of examiners, so as to ensure its substantial agreement with the provisional specification. Occasionally we have inventions protected by filing a complete specification at the outset, but personally I am not aware of a case in which the patentee did not regret the course he had taken in consequence of the expansion and modification his invention afterwards underwent. To remedy this, and at the same time to render the practice of filing complete specifications at the outset more favourable to inventors and more frequently adopted than at present, which I should consider a great boon, I would suggest the adoption of the system of granting certificates of addition to the original patent if filed as complete specifications. This system is in use in France and some other countries. These additions should also undergo a strict examination by competent examiners, to ensure that their contents were really of a nature cognate to the original specification. They, as well as the original patent, should be granted at a much smaller cost than now, for it is the poor inventor who wants assistance. The greater number of really valuable inventions emanate from the working classes. As it is now, many valuable inventions die with the inventor if he be poor, while in the United States, for instance, the small Government patent charges and generally judicious patent law and practice ensure the poor inventor ample returns for a small outlay, the community at the same time benefiting largely by their inventions.

Opponents to the grant of patents have said a great deal about obstructive patents, which I take to mean such as are kept in force by paying the requisite prolongation fees, but which at the same time are not really in force because they are not worked to the benefit of the community. I consider it far better to take this question in hand than to try to reason away what after all must be said to exist. With this in view I would propose the introduction of the system in use in almost all other countries, namely, the obligation of the patentee to work his invention within a certain prescribed period, which I would fix at five years. The working should be proved to be *bonâ fide*.

There is at present no penalty for omitting to mark a patented article with the word "patent." To illustrate the consequence of this omission in the patent law, I shall adduce an example from my own practice. A manufacturer of and dealer in sewing machines in a small way had a certain sewing machine sent him for disposal. It was fitted with a looper patented by a well-known firm, but contained no mark "patent," or words to that effect. Knowing that several other makers avail themselves of

the use of this looper by paying royalties to the patentees, and knowing the man for whom he was going to sell the machine, he did not for a moment doubt that royalties had been paid in this case, the machine not being new either. He had hardly sold the machine before he was called upon by the patentees' solicitor to pay a fine for selling the said machine without paying royalty for the looper fitted to it. In vain he protested his innocence and good faith in the transaction. To avoid expensive legal proceedings, he paid the fine and the solicitor's charges; sum total, 5*l*. The man for whom he sold the machine, as it turned out, was not the maker of it, and knew as little of it as the seller.

I wish to say a word about the indexes at the Patent Office. Irrespective of their accuracy, which generally leaves little to complain of, I must say that they are wholly unsuitable for the purpose of ascertaining the novelty of an invention. This point cannot be too strongly urged, for novelty is the very soul of an invention, and people should not unjustly be called upon to incur heavy outlays on what turns out to be worthless. I have repeatedly found inventions which require to be entered under more than one head, nevertheless entered under one only, and it is often quite a chance if in searching you do not miss the very thing you are looking for. I could adduce several examples were it necessary, but the fact is well known. I have been informed that the patent indexes in the United States are almost perfection in this and other respects, and further, that a search there does not occupy one-fourth the time it does here. If the present staff at the Patent Office is insufficient or inefficient, a larger and a more efficient one should be provided in that department. There are ample funds to pay for it, funds which are lying idle, and which ought to benefit the inventors out of whose pockets they came.

In conclusion, I may add that I thoroughly agree with the resolution of which notice was given at our last meeting, and which I have no doubt will be carried unanimously.

Yours faithfully,

To the Secretary of the Society of Engineers. (Signed) Peter Jensen.

Dear Sir, Middlesbro'-on-Tees, 28*th May*, 1870.

It is difficult to avoid the conclusion that opponents of the patent laws generally form their own opinions on grounds at the bottom of which lies some motive of self-interest. I do not say tha 's the case with Mr. Macfie, but it is easy to see

that it is the case with others who might be named. It appears to me that if the arguments of these gentlemen are valid at all against the protection of invention, they are also valid in equity against the protection of property of every kind. If a person with much labour and cost has perfected an invention, I have no right to found a profitable trade on the fruit of his industry; neither have I a right to ask for the repeal of a law which protects that industry. I do not think Mr. Macfie is blind to a sense of justice, but he appears to hold the opinion that nothing ought to be considered property except what can be touched and handled. You cannot touch or handle time, and yet by common consent time is as much the personal property of a man as his money is. Its value, in fact, lies at the very bottom of the Habeas Corpus Act.

It is very true that sometimes patentees are unreasonable, and a patent may become a nuisance, although this is not often the case. With regard to the simple justice of granting protection to inventions, let me put an actual case. A neighbour of mine has recently taken out a patent for improvements in smelting iron. He will, he says, be able to save the district 200,000*l.* per annum. As far as I am able to judge, the plan is likely to succeed, and the saving will in that case be very considerable. He asks for royalty $\frac{1}{11}$th of the saving, and he will probably get $\frac{1}{24}$th, which is reasonable. Now, if there had been no patent law, what would have been the result in this case? The inventor would not get a farthing. The manufacturers would put the whole of the profits arising from his invention into their pockets, and if he were a poor man (which however he is not), he might go to the workhouse unpitied. If such was the case, then, what was to be done? Mr. Macfie has said in effect, "Let the man go to Government for reward;" but in this case it would be to levy a rate on the whole of the public for the benefit of a few ironmasters. The notion is unstatesmanlike, and inconsistent with the proper administration of justice, because it is not the deserving who get rewards, but those who are most persistent in asking.

What, then, is to be done? The solution is simple and easy. Grant an inventor the protection of an efficient and equitable patent law, and then he falls at once into a position to which he is honourably entitled. As a common trader, he sells what he has got to those who are interested in buying; and if people will not buy, he loses by his speculation.

Yours very truly,

(Signed) R. Howson.

To W. Lloyd Wise, Esq.

October 3rd, 1870.

W. ADAMS, PRESIDENT, IN THE CHAIR.

THE THEORY OF SCREW PROPULSION.

By MICHAEL SEFI.

A few words of apology may be necessary for writing on a subject which has been given up by many as hopeless, more particularly as it has been repeatedly stated that practical rather than theoretical investigation is required. The author proposes to deal exclusively with common screws, believing them to be when well proportioned as good as any other form proposed, and better than a great many. His object in bringing the paper before the Society is to get elucidated as much as possible certain misty points upon which the theory of screw propulsion depends, and, in the absence of means to carry out experiments, to suggest a way in which those interested may be better prepared than they now are to draw correct conclusions from any subsequent experiments that may be made; and to supply a means of increasing the present knowledge of the action and results obtained from the screw propeller in ordinary practice by the simple statement, in a manner more lucid than that generally adopted, of the details connected therewith.

It seems to the author, that the general tendency is to attribute too great importance to the absolute area of the screw's circle of revolution, to the comparative exclusion of questions of pitch and area of blades and their relation one to the other. The ordinary method of computing the probable useful effect of any given screw from the area and velocity of the after stream is not only very rough but very incorrect, because by taking the area of the after stream into the square of its theoretical velocity as a measure of the thrust, or if the area of the screw's circle of revolution be taken and multiplied by the velocity, squared of its theoretical progress due to the pitch, into the revolution per minute, we assume that the pressures per unit of area, the direction of those pressures, and their resultant, are the same throughout. This we all know is not correct. According to the most authentic experiments it has been shown that a portion of each blade varying between ·2 and ·3 of its total height from the boss is comparatively inefficient. From a certain point in the

blade dependent upon the pitch the useful effect of each unit gradually decreases until, where in contact with the boss, it becomes almost absolutely nothing, and that portion of the centre of the plane corresponding to the boss would of course represent a negative pressure. It must from this be seen that a calculation which omits these considerations is erroneous.

It may be said that multiplying by a coefficient would represent these differences, but it will be seen that this coefficient would have to be different in every individual case, except under conditions of exact similarity in all details.

The area of the blades of a screw may theoretically vary between the 0 and $r^2 \times \pi$ (r being the length of a blade from the tip to the axis of the shaft), yet, *cæteris paribus*, the area of the screw's circle of revolution will be the same in both cases. But the lateral resistance caused by skin friction F will vary as the surface of the blade A; therefore in the first instance $F = 0$, but in the second it is $= r^2 \times \pi \times c$, where c is a coefficient of hydraulic friction, varying approximately as the velocity $\times 1 \cdot 7$ or $1 \cdot 8$, consequently having an absolute value about as the $1 \cdot 7$ and $1 \cdot 8$ power of the distance of each particular unit of area from the axis of rotation. Again, supposing even that the area of the blades or that of their aft projection were uniform from boss to tip, as the angles vary continually the resulting useful effect of each infinitesimal portion must be different. It will therefore be seen that, the resistances varying with each detail, they cannot be conceived even with any approach to accuracy if grouped up and expressed in the ratio of pitch to diameter, as now is generally done. Another inaccuracy which ought not to be permitted is the following:—It is generally accepted that the blades should not have a greater aft projection than about one-sixth of the total plane of rotation. Accepting this, for the sake of argument, as correct, it ought to occur to those adopting it that the pitch of the screw will make a long difference in such area S s in two screws of the same diameter. Let $a =$ the angle of any part of the screw, with its plane of rotation, and x its aft projection : $x :: s :$ cos. $a :: 1 \therefore S\,s \times$ cos. $a = x$. Cos. a decreasing inversely as the angle, it ultimately vanishes, when s would therefore be infinite, and x nothing for the base of very coarse-pitched blades; while, on the other hand, for the tips of fine-pitched blades cos. a may be made as near as we like $= 1$. The minimum of area denoted by the above expression is thus equal to one-sixth of the plane projections, while the maximum may be almost anything, the diameter, and consequent total area of plane of rotation, being in both cases identical.

Before proceeding further it will be necessary to say a word relative to the action and resistance of inclined planes moving in

water. In calculating the resistance opposed by the water to such a plane in the direction of its motion, it is customary to suppose that the resistance varies as the sine^2 of the angle which it forms with its line of progress, upon the hypothesis that the resistance varies as the V^2 of the displacement of the water. An unit of area of the inclined plane in question is supposed at a given velocity to displace, to a distance equal to the length of the unit into the sine of its angle of inclination, a column of the fluid, having for its base the unit in question, and for its weight that of a column of water of the height due to the velocity of lateral displacement, or to the lineal velocity of the plane × the sine^2 of its angle. Algebraically expressed it will be $\frac{A \times (V \times \sin. a)^2 \times a}{2\,g}$, where A is the area of the unit in square feet, V its linear velocity in feet per second, and a the weight of a cube foot of water. This would be correct if the water were the moving body, because then the linear distance traversed by each particle in attaining a certain height on the plane would bear the proportion of 1 to the sine of a if so measured; but when the water is at rest, and the plane in motion, the linear distance moved is then measured by what would be cos. a. Putting this distance equal to unity, the displacement becomes $= 1 \times \tan. a$. If this be true, it seems to the author that the resistance should vary as the tan. a^2. As an example, supposing that a plane be at an angle of 11 deg. 32 min. with the base, and consequently having a sine = ·19994, and giving an inclination of 1 in 5 nearly, disregarding friction, to draw any body when put in motion at a certain velocity up said plane, the plane being at rest, would require a force = ·19994 of the weight of the body; but if the plane be put in motion, and the velocity measured along its base, the body being only free to move in a line normal thereto, under the same conditions the dynamical force will equal $W \times 20406 \times V$, ·20406 being the tan. of 11 deg. 32 min. Although applicable to solids, when considered with reference to water it appears to the author that a considerable modification is required. Supposing that the plane be moved along under the weight W, at any velocity V, the dynamical force P required, disregarding friction $= W \times V \times \tan. a$, but by doubling V it becomes $W \times 2\,V \times \tan. a$, the dynamical force varying as the velocity. In water W represents the pressure of the fluid upon the plane at any velocity V; by ubling V, B becomes $= W^2 \times 2\,V \times \tan. a$. Consequently, tting Q for the factor of augmentation of V, the resist- e to the motion of an inclined plane in water would be as $\times\, Q\, V \times \tan. a$; or putting this in other words, if any given f an inclined plane be taken, having a relation of tan-

gent to rad. as 1 is to 2, by moving that plane at a certain velocity in the direction of its base to a distance equal to its length, a resistance will be overcome, due to the displacement of a body of water equal to its superficial area, to a distance equal to the tangent of its angle. If a solid had been moved, a plane having a rise represented by 1 to 4 of base moved at twice the above velocity would do the same work; consequently the power required will be that to overcome one-half the former resistance to twice the distance in the same time. If with respect to water the theory of the sine were correct, the resistance to the movement of the inclined plane might be arrived at in the same way, but the following results arrived at by Colonel Beaufort show that it cannot.

The following figures show the proportion borne by the effective resistance to that indicated by theory, which is represented by 1. At 30 deg. it was 1·1 to 1; at 19 deg. 28 min. it was 1·98 to 1; at 14 deg. 29 min. it was 3·24 to 1; at 9 deg. 34 min. it was 6·95 to 1.

As the theory of the sine ^{2} is nowhere near the truth, it is useless to admit it at all, and a solution of the question should be looked for elsewhere. What the author wishes to advance is that the resistance to all inclined planes may more correctly be expressed as some coefficients of the areas of their plane projection in the direction of motion into v^2; the theoretical would then come much nearer the practical resistance than as now calculated. In the example just quoted the area of the plane projection in the direction of motion being reduced by $\frac{1}{2}$, and the velocity increased by its reciprocal, the resistance varying as the simple power of the area, but as the square of the velocity, if it were a simple plane moving at right angles to itself the resulting resistance should be represented by $\frac{4}{2}$ of the former; of course being an inclined plane it will be less. This is a very rough way of putting the matter, but it would give a better result than calculations according to the theory of the sine ^{2}. In any case, however, it would be excessively difficult to arrive at a very close approximation of the total resistance of any inclined plane at a certain velocity, because experiments made by Mr. Colthurst and others some years ago show that greater pressure is encountered by the forward than the aft part of such planes moving in water. Two bodies were drawn by him through water at the same speed of 4·96 ft. per second; they were furnished with angular prows of the same inclination, *viz.* having a proportion of base to slant length of 1 to 3·3. One was constructed of exactly half the width of the other, and being immersed to the same depth of $4\frac{1}{2}$ in., the latter presented double the surface of the former.

By the experiment it was found that the comparative resistances were as 1·89 to 2·51, or nearly 3 to 4 instead of 3 to 6, which would have been the result if the pressure upon each unit of surface had been uniform. The views advanced with respect to the resistance of inclined planes seem substantiated by the indifferent results derived from screws having excessively fine pitches and running at high velocities, and by the glaring incorrectness of the theory involving the sine ^{2}, which was only found to be right at an angle of about 45 deg. In the author's opinion the parts of screw blades at this angle are for the following reasons doing the most useful work :—

Water is equally mobile in all directions; consequently, unless the pressure exerted upon each unit of area in all directions is equal, those portions subjected to the greater pressure will recede, which in the case of a screw is called slip, and this may be produced in one of two ways: it may either result from the water being carried round by the screw, or by its being driven aft. Whichever way the water is moved of course a loss results. In any portion of the blade of a screw the tendency to drive the water in one direction or the other might geometrically be represented by the sine and cos. of its angle of inclination with the plane of rotation; and as these will always be one greater than the other, except at an angle of 45 deg., it follows that this angle ought to represent theoretically the inclination of a plane which would distribute the power exerted most uniformly upon the water. Practically, the angle might be something less than 45 deg., as friction would tend to carry the water round with the blades. If the pitch of the blades be uniform throughout, the angle of any part, with its plane of rotation, will of course be as its distance from the axis; consequently, only one portion of the blade can be at 45 deg., and, if that be the most advantageous angle, the smaller the deviation made from it the better. To attain a minimum of deviation, it follows that this part of the blade should be situated about the middle of its length, as this would divide equally the disadvantages that would result from the coarser pitch consequent upon placing it higher (or nearer the tips), on the one hand, or those induced by the finer pitch consequent upon placing it lower on the other. This gives a pitch of about one and a half times the diameter. A few experiments, made entirely independently of this conclusion, during the regular working of two steame ing between Liverpool and the Mediterranean, show ave been the most advantageous pitch of any tried gs being the same.

T are a few details :—No. 1 steamer, built of iron l, in 1856 :—Length, 210 ft.; breadth, 29 ft.;

depth, 16 ft. to main deck, 7 ft. spar deck above; draught loaded, 18 ft. aft, 15 ft. 10 in. forward; carries about 1100 tons total dead weight; cylinders, 42 in. diameter, 30 in. stroke, direct-acting inverted; jet condensers; greatest speed in smooth water, with all in perfect working order, 9 knots; average on voyage with various weather and coal, seldom exceeds $7\frac{3}{4}$ knots. Three-bladed iron screw, 12 ft. diameter, 18 ft. pitch; revolutions, under most favourable conditions, 60 per minute, average about 57; safety valves loaded to 18 lbs., actual pressure varying between 13 lbs. and 16 lbs., seldom higher; vacuum, 24 in., occasionally, 25 in.; consumption, 19 tons Lancashire coals daily.

This steamer was tried under exactly the same conditions subsequently with an ordinary screw of the same area and diameter, but having a pitch of but 16 ft., and the result was that she fell off half a knot. The consumption increased to 20 tons per day, while the revolutions became 68. On another occasion she was fitted with a similar screw, but having a pitch of 22 ft. The result was that she only averaged 6 knots the whole voyage instead of $7\frac{1}{4}$, that is to say, fell off $1\frac{1}{4}$ knot fully, while the engines went only 48 to 50 revolutions per minute. The pressures carried were in each instance the same.

No. 2 steamer, built of iron for same owners, in Hartlepool, in the year 1855:—Length, 182 ft.; breadth, 27 ft.; depth, 14 ft. 6 in.; draught loaded, 15 ft. aft, 13 ft. forward; carries about 630 tons total dead weight. Engines, direct-acting inverted; cylinders 34 in. diameter, 27 in. stroke; jet condensers; vacuum 26 and 27; best steaming in smooth water, $8\frac{3}{4}$ knots; average on voyages, $7\frac{1}{2}$ to $7\frac{3}{4}$ knots. Screw, common three blades; diameter, 10 ft.; pitch, $14\frac{1}{2}$ ft.; revolutions, 62. Consumption of Lancashire coal, about 14 tons daily. Model of ship sharp and fine at ends. This steamer was afterwards tried with a screw of 13 ft., same diameter pitch, but the results being unsatisfactory, it was resolved to return to the original propeller. Two other steamers, with which the author has had more or less to do, built two years ago, and fitted with screws of this pitch, are giving excellent results, as the following details will show:—They are sister ships in all respects, built almost simultaneously, and engined by one firm from the same patterns and drawings; but, like all sister ships, one seems to have a slight advantage over the other in point of speed, and one is a little addicted to priming, a vice that the other is free of. Their length is 270 ft.; breadth, 31 ft. 6 in.; depth, moulded, 21 ft. 4 in.; draught forward, loaded, 16 ft. 10 in., and aft, 18 ft. 4 in.; tonnage, 1200 register. Screws, cast-iron three-bladed, common type; diameter, 14 ft.; pitch, 21 ft.; length, 2 ft. 2 in.; total area of three blades, 59·88 square feet;

area of plane projection, 153·93 square feet. Engines, direct-acting inverted, 36 in. cylinder, 42 in. stroke; weight on safety valve, 40 lbs.; ordinary working pressure, 25 lbs.; surface condensers, vacuum, 26½ inches; revolutions varying between 50 and 54; average speed about 9½ knots, but whole day's steaming, without any sails and a slight breeze ahead, have shown 10 knots, or 240 to 245 miles per day. On trial trip the maximum speed attained was 12½ knots, the engines making 68 revolutions. A whole hour's continuous steaming showed 12 knots, with 63 revolutions. Average pressure, 29 lbs.; vacuum, 26 inches; draught of ship forward, 7 ft. 3 in.; aft, 14 ft. 8 in.

If the before-mentioned results go to prove that the theoretical deductions are justifiable, the blade might well be made proportionately wider than ordinary at that part having an angle of 45 deg., and the tips narrower, as this allows for the greater development of the best portion of the screw, and for the utilization of a greater portion of the available power in a more advantageous manner than would otherwise be the case. To this may certainly be attributed a portion of the improved results sometimes obtained by rounding off the tips of blades, and consequently reducing their area at the extremities; for, putting aside for the moment questions relating to the pressures induced by the passage of inclined planes at small angles to their line of motion through the water, which are not well understood, as the actual velocity of the outer parts of the blades is in every case (and more especially in that of fine pitches) considerably greater than the theoretical advance due to the pitch, and as the resistance in each direction varies about as the V^2, it follows that the lateral resistance due to friction increases much faster than the after thrust, and that the smaller the frictional surface the better. This therefore goes to show that the minimum of area of blades necessary for propulsion will be the best, and that fine-pitched screws, revolving at high velocities, are wasteful of power. The friction of water, unlike that of solids, does not depend upon any coefficient of absolute weight or pressure, but upon the velocity squared with which the body passes through it.

According to Professor Rankine, the frictional resistance R of clean painted iron ships is 1 lb. per square foot at 10 knots varying as the velocity squared. According to Mr. Scott Russell this resistance is 1 lb. per square foot per foot per second, also varying in the same ratio. Applying Professor Rankine's computation to any surface of any given area a, the frictional resistance in 1 lb. becomes $= \frac{a \times V^2 \text{ (in knots)}}{100}$. When applied to a screw, as the friction will vary as the distance[2] of the part

from the axis, it is necessary to divide the blades into spaces by ordinates K, say 1 ft. apart, and the calculation becomes

$$a\left\{\frac{\sqrt{(2\pi r)^2+P^2}\times x\times 60}{6082\cdot 66}\right\}^2 \div 100 = F$$

nearly in lb., where P = the pitch of the screw, a = the area of the space enclosed by any two ordinates (K), x = number of revolutions per minute, F frictional resistance, r distance of centre of area enclosed by ordinates from the axis. And putting

$$a\left\{\frac{\sqrt{(2\pi r)^2+P^2}\times x\times 60}{6082\cdot 66}\right\}^2 \div 100 = S_1$$

the total resistance in foot pounds becomes

$$\frac{\left(\frac{a\,1\times s_1^2}{100}\right)\times r_1+\left(\frac{a^2\times S_2^2}{100}\right)\times r_2+(a\,n\times S\,n)\ \&c.}{K\,n}$$

The value of

$$\frac{A\,n\times S\,n}{100}$$

increases as r^2; consequently the dynamical force required to overcome it varies at r^3. From this it is easy to see how enormous the frictional resistance may be made by overloading a blade at the tips with surface.

The proportions of screw blades with respect to surface are in a more unsatisfactory state than that of any other question relating to screws. In practice the fault seems always to have been to err on the side of too much surface; consequently the limit of economical area has been reached and passed on that side, and the question that now remains to be determined is the limit of surface on the other side. The question of area seems to resolve itself into one of great surface, s_1, and small pressure, P, per unit of surface, or one of small area and great pressure. The values of P and S, therefore, vary reciprocally, but both vary as r^2. The problem seems to be to determine the most advantageous value of P for the different radii. As every cubic foot of water abstracted from the stern of a ship represents an equal increment of pressure at the bows, tending to retard the speed, it follows that a small quantity of water reacted upon at high pressure is more advantageous than a larger quantity reacted upon at a low pressure. Again, according to all authorities, frictional resistance increases about as the area into the V^2, or into the 1·8 power of the

velocity; but, according to the same, the pressure upon an inclined plane moving through water, although varying about as V^2, is not directly as the area, but varies in a smaller ratio. Therefore, after a certain width of blade has been attained, the useless resistance increases faster than the pressure due to the velocity.

With reference to Mr. Rigg's theory of inclined paddles, and repudiation of that generally accepted of the propeller screwing its way through the water, they appear to the author, to a certain extent, reconcilable one with the other. The ordinary theory takes into consideration the effect of the action of the screw; Mr. Rigg's, the result of the effect or the deflection of the water by the blades. This seems, however, to have but little to do with the action of the propeller, as such water, after it has once passed it, has nothing to do with the propulsion of the ship. If the screw be supposed working in undisturbed water, the action would be about the same as that of any inclined plane acting in a solid body, the only difference being that the solid body retains its shape after the action, while the particles of water, being free to move in any direction, naturally follow the line of least resistance or greatest impulse. Summarizing what the author has in the foregoing endeavoured to express, the following questions present themselves:—In any given screw, what should be the diameter pitch, and area, and the position of maximum area? It being acknowledged by all that the diameter should be as great as the draught of the ship will allow, this is easily answered. As to pitch, the author hopes to have shown theoretically, and by such few experiments as have been available, that a pitch of one and a half times the diameter is at least one of the most advantageous. The next point is certainly the most misty. The maximum of area having been attained, the minimum should be determined; what this minimum may be it is excessively difficult to arrive at by inductive reasoning, the more so as it imports into the subject questions relating to the economical speed of the engine. Theoretically, area and velocity vary reciprocally; therefore, a reduction from a given area would have to be made up by an increase of velocity, or *vice versâ*. It may perhaps be attained when the work done in driving the engine light at the velocity of the screw and loss in slip bears a minimum proportion to the total power expended in propelling the ship.

Lastly, the greatest width of blade. This should be in the most advantageous position, and if what has been said respecting planes at an angle of 45 deg. holds good in screws having a ratio of pitch to diameter as 1·5 to 1, it should be about the middle of the length of the blade. In screws of finer pitches it might

be somewhere nearer the tips than the line of 45 deg., to avoid as much as possible the broken water left by the stern.

As a simple way of enabling a better judgment to be formed, and of increasing the existing very slight knowledge of the right proportions to be given to different screws, the author suggests that in the description of every such propeller as given by the engineers, instead of stating only the diameter and pitch, that the diameter of the boss be given, also that the blades be supposed traversed by ordinates 1 ft., or in smaller screws 6 in. apart, commencing from the tips of the blades, and that the length of each ordinate and its angle with the plane of rotation be stated.

As an example, he gives the following, which are details of the screws of the sister ships already alluded to :—

Pitch, 21 ft. diameter; boss, 2 ft.; ordinates, 1 ft. apart.

1st	ordinate length	4·65 ft.	angle	26	deg.
2nd	"	4·	"	30	"
3rd	"	3·33	"	35	"
4th	"	3·	"	43	"
5th	"	2·65	"	54	"
6th	"	2·33	"	68	"

Consequently, as there are six ordinates to each blade, and 2 ft. of boss, the diameter of the screw will be 14 ft.

These dimensions are all easily taken in a few minutes from the drawing of the screw, or if only the lengths of the different ordinates be given they will show the width of the blades at the different portions, and the angles can easily be calculated from the pitch, either trigonometrically, or by geometrical construction. From this a comparative coefficient might perhaps be deduced about as follows :—

$$\sqrt{r_1^2 + r_2^2 + r_3^2} + r_n^2 \times \left(\frac{S\,A}{n\,K}\right)\left(\frac{S\,\theta}{n\,\theta}\right)$$

where $\frac{S\,\theta}{n\,\theta}$ = sum of the angle divided by their number = the mean angle, and $\frac{S\,A}{n\,K}$ gives the mean area.

Even the most intelligent man might puzzle himself for an unlimited period with the meagre details ordinarily furnished, without being able to make anything out of them; so it is of great importance to the cause of screw propulsion that the above-mentioned system or something similar be adopted, more particularly because the immense expense of the experiments necessary precisely to determine what it is requisite to know causes them to be deferred from year to year, while badly

designed screws are being driven at a cost for fuel out of all proportion to the useful effect produced.

The author has proposed that the before-mentioned data be given by the constructors of screws and engines, in conjunction with other details of ship and machinery, and results obtained, as an approach to something definite, and as a step towards giving some criterion by which to judge of different screws. This was shown to be necessary in the beginning of the paper, in mentioning the incorrectness of grouping the resistances together in the simple terms of diameter, pitch, and velocity.

In writing the present paper the author has painfully felt the want of reliable unbiassed information, and the scantiness of the details noted on all occasions where screws are dealt with; and it is necessary to state that the paper has therefore fallen considerably short of what was intended.

With reference to experiments, it would be of but little use to try them by driving propellers of different dimensions in the ordinary way, as they would only be like a repetition of those made in the years 1844–5 with the 'Rattler' and the 'Dwarf,' from which it seems comparatively nothing conclusive has been learned. On referring to an account of these experiments to ascertain the date, the author finds the following statement:—"The most favourable results were obtained from a double-threaded screw of 5 ft. 1 in. diameter and 8 ft. pitch. During one experiment the length was 1 ft. 6 in., and the area 13·3 square feet, the speed attained being 8·94 knots; and it is remarkable that in the experiment following, when the length of the screw was reduced to 1·1 ft., and its area to 8·9 square feet, there was comparatively little variation in the resulting speed of the vessel or screw, the speed attained being 9·11 knots. This was the best result of the whole series." The reduction of area would, in the author's opinion, have given better results, but that cutting a blade away leaves very thick edges to bruise and lash the water about.

The screws experimented upon were all 5 ft. 1 in. in diameter; the pitches 8 ft., 10·32 ft., and 13·23 ft.; and although the most advantageous area of 8·9 square feet was tried at all these pitches, that of 8 ft., or about one and a half times the diameter, gave the best result. Having arrived at the conclusions already expressed, without knowing the details of the 'Dwarf's' experiments, the author merely quotes them in corroboration of the ideas advanced. In case of a further series being undertaken he proposes to the consideration of the Society that they be made somewhat as follows:—

That an ordinary screw, say, having two blades, and a diameter of perhaps 10 ft., pitch 15 ft., and length of 1 ft. 6 in., be

cast and fitted to a shaft set up in bearings in the basin of a dock, with no more obstruction to the free run of the water than is necessitated by the bearings, &c.; this to be driven by an endless band from the shore by the most powerful and nearest engine available, if possible of not less than 80 to 100-horse power nominal. The screw first to be driven at a low speed, and its velocity afterwards increased, say, five revolutions at a time per minute, until the maximum driving power of the engine is reached. Each separate speed to be maintained for a space of time sufficient to observe and note the results in a reliable manner; the direction and pressures of the currents produced being measured by means of vanes or other suitable method. The resistance to turning to be measured by means of a dynamometer on each shaft, the proper allowance being made for friction at the different velocities. The thrust to be measured either under water or by means of a lever in contact with the end of the shaft, reacting upon a dynamometer in any convenient position.

Next, that four or eight (or as many as may be decided upon by those entrusted with the experiment) bosses exactly similar to that of the perfect screw be cast and fitted to the shaft, and tried separately at exactly the same number of revolutions as the screw, the first boss carrying portions of the blades up to 6 in. or 1 ft. from the boss (according to the number to be experimented upon); the second to carry 2 ft., the third 3 ft. of each blade, up to the fourth, which will form a perfect screw, having a diameter of 8 ft. and a pitch of 15 ft. The next 2 ft. of surface will be represented on the perfect screw. The tips of each portion to be struck to the radius of the circle which they describe. If the resistances given by each at the different velocities be carefully noted, the increment of observed resistance can only be due to the increase of area.

It is evident that this method of experimenting might be extended indefinitely according to the inclination of the experimenters and the funds at their command; and the resistances due to each particular division of the blades, and their variation at different velocities, must be arrived at with a much greater degree of precision than would otherwise be possible. It might be advisable to cast the boss separately and bolt the blades and portions of them to the same in the ordinary way for screws with shifting blades, but as the suggestion is simply in outline it would be useless to occupy the time of the Society with details. The author brings the above suggestion relative to future experiments before the Society, because although all agree as to the necessity for such experiments, no one seems to have any very decided idea of the particular way in which such

experiments should be conducted; and in the author's opinion, if tried on a ship and propeller under ordinary circumstances, it would be difficult to know in what particular direction to look for the lessons to be learned, or to separate the reliable portion of the results attained from the influence of extraneous circumstances.

DISCUSSION.

Mr. OLRICK observed that the author of the paper had stated that 45 deg. was the proper pitch for a screw propeller. That was corroborated by his (Mr. Olrick's) experience, although the rule was not absolute, as there were circumstances affecting the pitch, such as the length and area of the propeller, which in some cases would modify the angle. The author had also correctly stated that it was wrong to have great width at the tip of the screw, as much of that surface was wasted. It had been found by experiments that if the leading corner of a screw blade was cut away, the screw gave from seven to ten per cent. better results than when the corner was on. The reason was that instead of the leading corner lashing the water away, the blade with that corner cut off entered the water gradually, and so took hold of the water as the whole area acted. It was very desirable that there should be a series of thoroughly exhaustive experiments made with the screw propeller, as there was only a limited amount of knowledge extant respecting it at present. Indeed, engineers knew nothing respecting the behaviour of the water which came in contact with the screw propeller. Mr. Sefi suggested that experiments should be made with a screw propeller in a stationary vessel; that would be better than not having any experiments, but it would be better still to make the experiments with a vessel in motion, and under the actual conditions of work. The experiments would be more expensive than those proposed by Mr. Sefi, but they would be more conclusive and satisfactory.

Mr. GALLOWAY said, having made some experiments with screw propellers, he had been led to the conclusion that those in ordinary use were wrong in form. He therefore devised two different forms of propellers, models of which were placed before the meeting, and in which the leading edge was entirely cut off, the driving surface being brought down in a line with the shaft. By reducing even the shaft to the thickness of the boss there would be less resistance to the progress of the ship, and consequently a much better effect would be produced by the engine power. That screw he designed about eighteen years since, and he had experimented with it against a model of the Admiralty screw propeller of that time, and the result was that with the Admiralty propeller it took 16½ seconds to run a distance of

72 feet, and with his propeller the time never exceeded 15 seconds; therefore the result was in favour of his propeller. The model was driven by a spring action, and it was observed that with the Admiralty screw there was a great roughness in the water, which was broken up very much. The fact was that in propelling a ship with two propellers on one boss a large amount of power was necessarily wasted, because the second propeller upon the same boss was not effective in the same ratio as the leading propeller was, but if they were placed some distance apart there was time for the one to keep free of the other, and they would give very much better results. Professor Rankine had assured him that the difference between the engine power and the effective result of the best screws in use was something like 25 per cent., which showed that the form of screw generally adopted in practice was not correct.

Mr. SCHONHEYDER referred to a statement made by the author of the paper to the effect that Mr. Rigg's theory that the water after having left the screw could not possibly be made to assist in the propulsion of the vessel, was incorrect. He (Mr. Schonheyder) did not see why the water should not be made to assist in the propulsion of the vessel after it had left the screw. He would suppose the water had not been driven in a rotary motion by the screw, but by some other means; for instance, by a pump at the side of it; if that jet of water was made to impinge upon a slanting blade fixed in the after-part of the ship, there was no doubt there would be propulsion produced, and which would be similar in action to the wind upon the sail of a ship in a slanting direction, which propelled the ship. Just the same in a screw vessel: when the screw, of whatever shape it was, acted upon it, it drove the water partly in a rotary direction and partly in a lateral direction. The result of those motions was a sloping direction, partly aft, partly sideways. Only the part of the motion which went aft was utilized in propelling the vessel, and the part of the motion which went in a rotary direction at right angles with the keel of the vessel was entirely lost in propelling it. If a jet of water was driven against a sloping blade fixed at a proper angle, it would certainly be utilized in driving the ship forward. Although he was not prepared to say what the exact shape of the screw should be, yet he thought most screws were made wrong. Certainly the ordinary shape of screws—the uniform pitch—was quite wrong, because it was a physical impossibility to make the whole surface of the blade act upon the water in propelling the vessel. In his opinion the after-part of the blade—that was, the part of the blade which came last in the rotation of the screw—simply acted in retarding the progress

of the vessel, and he did not see why the theory of screw propulsion should not be based upon the theory of turbines. The screw might be considered an inverted turbine. In a turbine a jet of water produced a rotary motion on a shaft, whilst in a screw propeller the reverse was the case—the propeller rotated and produced the after stream.

Mr. W. Lloyd Wise said that his late father, many years ago, took considerable interest in the subject of screw propulsion, and in 1855 was engaged in designing some small screw-boats in Belgium, when to the best of his the (speaker's) recollection, his experiments led him to conclude that the form of vane now proposed by Mr. Galloway was the best.

Mr. Macgeorge said that from his experience he believed that increasing the pitch in the after-part of the blade was better than cutting off too much of the leading corner, because he had found that when the point of the blade was made too narrow, a great deal of the useful effect was lost. What was called a fine pitch of the propeller was a very great evil, as the blade formed an inefficient propelling angle to the water. He thought the leading edge of the blade should be sparingly reduced and the pitch of the after-end increased in the way that Mr. Schonheyder had mentioned. There was no doubt that whatever velocity the propeller gave to the water was power to a certain extent, and if the motion was oblique, that power could be utilized by such deflecting blades as Mr. Rigg advocated and which he had tried. But the velocity of the water was not great. It was only the difference between the velocity of the ship and the velocity of the current leaving the screw, but nevertheless it was power, at least it was the dynamical element of power, and reaction against the deflecting blades he had alluded to would give the statical element. The whole power would thus be absorbed in the propulsion of the ship just as a turbine was thoroughly efficient only when the water leaving it had no velocity, and therefore no element of force unexpended. With the general conclusions of the paper he agreed, only he thought the angle of 45 deg. was rather too great for practical purposes. He thought that an angle of 43 deg. would be the maximum propelling angle of a good propeller, and the minimum 28 deg., and that between the two the best results would be obtained. With reference to the experiments which the author of the paper made when the pitch was increased, he mentioned that the pressure of the steam was the same in both cases. Of course that ought not to have been the case, because the propelling pressure being greater the steam pressure ought to have been greater also, he ought to have had the same indicated power in working in both cases, whereas the pressure remained

the same and the velocity diminished. If the indicated power had been the same, no doubt the result would have been much better with the increased angle. His own practical experience without reference to theory agreed with the general conclusions stated by the author of the paper.

In reply to a question from Mr. Olrick, Mr. MACGEORGE said he did not believe there was any such thing as negative slip in screw propellers.

Mr. OLRICK said he had been on board ship many years, and was satisfied that there was actual negative slip, because the velocity attained on the measured mile was considerably greater than the calculated distance that ought to have been accomplished by the propeller.

Mr. MACGEORGE said he had not the least doubt of that, but that went on the supposition that the propeller was really a screw, but the ordinary propeller had no element of the screw in it. If the propelling angle was a right angle to the keel, it might be called a screw, but it would not propel any more than if the angle of the blade was made parallel to the keel. It would have no effect whatever, and if the angle was altered to any degree between the two, the result would be the best propelling angle; whereas, if it was made a true screw, it might properly be called a screw, but it would not act as a screw. If it was advancing in a solid the ship would always move at exactly the same rate that the so-called screw would, and the very fact that it did not do so was one reason why he was justified in saying it was not a screw, but simply an oblique-shaped paddle. Considering it as a propeller, of course negative slip did exist. Mr. Burton gave as a reason, that there was a current following the ship which the propeller acted upon and had an additional power, but then the engine itself produced that, and to say the best of it, it was only a mitigation of the evils of wasted force.

Mr. OLRICK agreed that the screw propeller was not a screw in the strict sense of the word, but Mr. Macgeorge had forgotten that it was only the external part of the blade that gave out the propelling power. The blades of a propeller might be continued until a true screw was produced, just as a true screw could be cut down to a propeller.

Mr. MACGEORGE wished it to be understood that, although the propeller was not a screw in shape, he believed it could be made a very true screw; but its action on the water was not the action of a screw, which must be assumed in order to believe in the existence of negative slip, or to believe in slip of any kind. Owing to water being mobile, the propeller could not act as an ordinary screw. According to the shape of the ship, there were

currents from different directions. If it was a very full stern ship, there were currents moving in one direction on one side and in a different direction on the other. The propeller had to deal with all those currents, and it was exceedingly difficult to know what really was the angle of the water the propeller acted against. His conclusions had not been arrived at by theory but by observations in practice, and he believed that the actual shape of the propeller might be a screw; but it did not act as a screw, and that was what he meant by saying that it was not a screw. When the propeller was made a true screw with a fine pitch, the propelling angle was very bad at the boss and only partly efficient at the extremity. To avoid that, he thought the propeller should be a true-shaped screw, starting at the boss at a pitch, which at a given number of revolutions of the shaft would neither propel nor retard the ship, and he would continue that pitch to that diameter of the propeller at which the angle would be 45 deg.; he would then gradually increase the pitch to the circumference of the propeller, where he would make the propelling angle about 28 deg. or 33 deg., and increase the pitch to 2 ft. more on the trailing edge. He cut very little off the leading corner. The necessity for doing that in some propellers was shown after the propeller had been working some time by the blade being honeycombed on the back by the pressure coming on the wrong side; and when the blade was twisted about by increasing the pitch on the following or trailing edge, that did not occur.

Mr. Sefi, in replying upon the discussion, said that with respect to what Mr. Olrick observed about cutting off the leading corners of the screws, he did not think that it acted entirely as he had stated. He thought that it was to some extent due to the deflection of the water before it arrived at the portions that were placed in the after-part of the blade, the same as had already been proved by the experiments he (Mr. Sefi) cited before, which were made upon two planes, one having double the area of the other, and in which the one of double the area did not give double the resistance. He did not think it was so much a question of the after-part being allowed to catch hold of the water, as it merely acted against water which was already in motion. In any case, of course, a screw having an increased pitch towards the after-part of the blade would be theoretically better. It had been objected that the experiments he proposed in the dock would not give the pressure. It seemed to him that whether the ship were going or perfectly stationary, the pressure would be the same, and would be recorded by the dynamometer. As the great point was to arrive at an exact [illegible] he wished to eliminate from the proposition

anything that might vitiate that result, because engineers were not sufficiently strong in the theory of screw propulsion to be able to define under ordinary circumstances what was really true and what was not; and that was the reason why he proposed that the experiments should be entirely free from the currents that were produced by the ship. Mr. Galloway's screw was a perfect plane, and it therefore appeared to him (Mr. Sefi) that the lower portion of the blade must be striking the water on the forward side, because the lower portion of the blade would not travel as far for a given revolution as the upper portion. He should make the angles more acute towards the boss. If it were not of uniform pitch throughout, some portion of the water must strike it. It must drag a portion of the screw while the outer parts of it were doing all the work. His remark as to the angle of 45 deg. did not seem to be quite understood. What he merely wished to prove theoretically was, that as water was equally movable in all directions, and as the angle of 45 deg. gave the distribution of power equally on all sides, therefore a greater thrust should be got out of that portion of 45 deg. A screw of 45 deg. might be anything and have a pitch of a great deal more or less than one and a half times the diameter, and yet contain the angle. What he suggested was, that the deviation from the most advantageous angle should not be greater than absolutely necessary, and therefore that the portion of 45 deg. should be placed near the middle of the blade, so that the deviation on one side and the other should be the least possible. With respect to Mr. Rigg's vanes, he had heard on more than one occasion that the resulting useful effect was most minute. And another thing was, that the currents deflected from the screw (both by Mr. Rigg's showing and by that of everybody else who adopted the theory) were driven in all directions. If that were the case, what was the most advantageous distance from the boss for the screw to be placed at? If placed below, then there must be some resistance due to the spindle that held the blade. Unless the spindle was of considerable strength, it could not hold a blade large enough to have any effect upon the ship. Of course, the longer it was made the thicker it would have to be made, and consequently the more water it would displace and the more resistance it would offer to the progress of the ship. It would throw up a regular current, like a second stem. He might state that one of those steamers he mentioned at the beginning of the paper went through the Suez Canal twice. She got ashore on account of one of the dredgers being in the way, and she damaged her screw. In coming home, and when in the Bay of Biscay, she broke off one of the blades which she had damaged in the Canal, and the vibration was so great

that by the time she got into the Mersey the screw was gone. The consequence was that she had to have a new screw, and according to the conclusions he arrived at in thinking the matter over, it was resolved to reduce the blades by 9 square feet. This was done, and the ship made the most successful voyage she had ever done, so that it seemed to show that there were some 9 or 10 square feet too much area in the screws. It was not generally supposed to be a matter for any decided opinion as to what number of blades a screw should have. It appeared to him that so small a number of blades as two could not be the most advantageous, because if a certain amount of area would propel a ship, there was the evil of the water being already in motion before it was taken hold of by the after-portions of the blades, whereas with a screw having a greater number of narrower blades each arrived at an extent of water that had hardly been put in motion by the one preceding it. Consequently a subdivision of the blades would give the maximum pressure obtainable on the fore-portion of a wide blade, and therefore a greater total thrust for a given surface. With regard to negative slips, he perfectly agreed with Mr. Macgeorge in not believing in it. He thought there must be a mistake somewhere, or that it must be the effect of some current, because it was perfectly impossible that a ship would go faster than its only means of propulsion could drive it. People pretended to believe in negative slip because they did not know how to disprove it; but at the same time, when they came to look at the matter closely, they found it to be impossible. It was certain that a ship could not go faster than the screw drove it, unless something else supplied the extra power.

The PRESIDENT said it would be interesting to know the gradual steps through which the screw had passed since its earliest adaptation to propulsion. Mr. Galloway's proposition was a very interesting one. As he understood it, it appeared to be a kind of double-threaded screw. It seemed to open out rather a new feature, and it would be acceptable to the Society if Mr. Galloway could place some further information of a practical nature before the members at a future time.

November 7th, 1870.

WILLIAM ADAMS, PRESIDENT, IN THE CHAIR.

THE ECONOMICS OF RAILWAY MAINTENANCE.

By EDWARD S. CROMPTON.

The provision of speedy, safe, and economical facilities for internal communication in a civilized country is of paramount importance, for without these facilities such a country can never attain to the complete development of its material resources, nor fully make available for the general good the riches that lie hidden in its half-cultivated soil, nor utilise the mineral wealth that lies buried in the bowels of the earth. Without the power of easy locomotion, its people will not possess those inducements to improvement which travelling and mutual intercourse produce; they will become dwarfed in their ideas, as well as in their resources, in comparison with the inhabitants of other countries more favourably circumstanced. Without good facilities for internal communication, the most wealthy country will fail to maintain a commanding position in the comity of nations, and is sure to lose ground in the march of human progress.

This will be apparent when we remember that upon the quality of railways, roads, and canals, depends, in a great measure, the speedy interchange and distribution among mankind of those products of the soil, loom, or anvil, which the energy, ingenuity, and perseverance of nations have prepared by the means of advantages peculiar to localities. Viewed in a military aspect, the value of good internal communication has been forcibly illustrated in recent wars, as it affords a speedy method of massing troops, bringing up reserves, and providing the means by which an efficient commissariat can provision large armies in the field. Numerous illustrations have been afforded of the uses to which railways can be applied, by invading as well as by defending armies, during the struggles in the Crimea, North America, Abyssinia, and more recently in Germany and France.

The ancient Romans built their roads with the stability and magnificence of a great people. As an aggressive and conquering nation, they fully realized the necessity for good means of

communication between the seat of government and the distant provinces of the empire. The author has often been struck with the ample width, good drainage, and directness of these old roads, and by these qualities he has been reminded of the long lengths of straight, ample width of formation, and durable structures on our early railways.

Towards the close of the first quarter of the present century, when trade had revived from the depression consequent upon our long and severe struggle in the Napoleonic wars, all our available means of carriage between the chief seats of manufacture and the seaports were, we are informed, becoming inadequate to meet the demands upon their powers of transport, and, had it not been for the introduction of railways, our trade and manufactures would soon have languished for want of a proper circulation of manufactures and raw material. Efforts had already been made to diminish traction by laying down rails or plates in order to facilitate the locomotion of wheeled vehicles. In 1801, the first railway Act received the sanction of the British Legislature: the author alludes to the incorporation of the Surrey Iron Railway Company—a trifling affair viewed as we needs must view it now—in comparison with the prodigious works around us, for it extended only from Wandsworth to Croydon, and was merely applicable for the carriage of coal, lime, &c., the moving power being from horses alone. It was not, however, until the commencement of the second quarter of this century, that railways worked by locomotives were first introduced. Since that time they have become our chief means of internal communication; their ramifications have pervaded the whole country, and there is scarcely a town with more than two thousand inhabitants which has not a railway station within easy reach. The Stockton and Darlington line, which was opened on the 27th of September, 1825, has become the nucleus of a system of internal communication unequalled in the extent and stability of its works, as well as in the capital and energy displayed in their construction, by any in the world's history.

Immediately after the formation of railways, the maintenance of the road was as little understood as the working of the traffic according to modern notions. In both departments, the experience brought to bear had merely been obtained in the colliery lines of the North, and our railways since their inauguration by that great genius of his time, George Stephenson, have undergone changes and modifications in important respects, both in traffic arrangements and maintenance.

As an illustration of the development of our passenger train service i [illegible] ountry, the author may here remark that he has in [illegible] sion a Bradshaw's 'Railway Guide,' published

in the year 1840; it is a little book measuring 4½ inches by 3 inches, and contains 26 pages, twelve of which are maps. Contrast this little book with the Bradshaw of to-day, which contains 400 pages of closely-printed railway time tables. The first railways, though experimental, were happily designed, as regards general stability of works, to suit the requirements of present traffic. Our first railway engineers appear to have foreseen the ultimate development of our railway system, and constructed those on which they were engaged, such as the Liverpool and Manchester, the London and Birmingham, and the Grand Junction Lines, on a scale suitable for trunk railways.

Now that this country is so thoroughly intersected with railways, and the prospect of the formation of any extensive new lines is so exceedingly small, their construction has had to give place in importance, of late years, to the study and direction of their safe maintenance.

It is contemplated in this paper,

1st. To give a short *résumé* of the past history of railway maintenance.

2nd. To describe the present practice of railway maintenance, and to indicate a few alterations that may be introduced in view of the available materials and possible requirements of the future. The subject may be classified as follows,—Works, Roads, Signals.

ORIGINAL WORKS.

The works on our early railways left little to be desired as regards stability. The author has recently had a forcible illustration of this fact in having had occasion to superintend the removal of two or three arched bridges, for widening purposes, on one of our principal main lines. The difficulty in hewing down these arches was a good guarantee for the stability of those that remain. As illustrations, he may state that a brick arch over the railway, with a span of 30 feet, and width of arch, including parapets, amounting to 36 feet, containing five half-brick rims, interlocked or bonded together, which had been erected above thirty years, retained its contour and did not give way until after upwards of 90 per cent. of brickwork had been removed from each springing, and holes cut in the crown. Another arch on the same line of railway, of similar span and 28 feet wide, could not be removed until after the whole of the brickwork had been cut through, from one side at springing, the weight of the arch then being too much for the adhesion of the mortar on the opposite side to hold the brickwork together.

Scarcely sufficient margin was left between the ultimate breaking strain of a few of the old cast-iron girder bridges, and

the total load that could be placed upon them, to allow of the increase in weight which has taken place in the locomotive since they were erected, but these bridges have easily been strengthened by additional girders; or where modern practice, with a fuller knowledge of the properties of cast and wrought iron, required such an alteration in the superstructure, by girders of the latter material.

Timber has been extensively used for under-bridges over rivers and back-water-courses, in the formation of several branch lines in the Eastern and East Midland Counties. The style of construction adopted in these bridges was generally as follows:—The railway was supported on a series of tressels formed of piles, cross-braced, and placed in tiers, from 12 to 14 feet apart, with longitudinal baulks to carry the rails. These bridges extend considerably beyond the margin of the ordinary water-level, to allow for flood water, and to prevent its being retarded in its flow over the sluggish watershed of the Eastern Counties. With a more intimate knowledge of the district, and the cost of repairing this class of structures, it has been found more economical to reconstruct them as they became decayed, with brick and iron, thereby saving expensive labour, such as carpenters and smiths, as well as timber and iron for scarfing piles and extra cross-braces. The erection of upwards of forty of these bridges, of various lengths and heights, has, during the last nine years, come under the author's notice. The plan usually adopted in the long bridges was to build brick piers in the centre of each alternate bay for the flood-water portion, and to divide the ordinary water-way into two or three spans, to suit the navigation, and was found, on calculation, to be most economical, taking into consideration the extra cost of the construction of the piers in water on one hand, and the additional expense of girders of long span on the other hand. The spans of the flood-water portion range from 20 to 25 feet; the girders were of cast iron, one under each rail; the spans of the river or navigation portion range from 40 to 50 feet; the girders were constructed of wrought iron.

The following facts should be taken into consideration by the maintenance engineer before recommending a defective pile bridge for renewal, either as originally constructed, or with materials of a more durable character.

1st. Will the annual expenditure of repairs to the timber bridge in question soon exceed the interest at say 5 per cent. on a sum of money sufficient to rebuild it?

2nd. Considering the kind of structure to be erected, the annual repairs to the timber bridge and brick and iron respectively should be computed and added to the sums of money it

is estimated their erection will require, plus compound interest at 5 per cent. per annum on the totals in each case.

3rd. Will the permanent character of the brick structure warrant the excess in expenditure for its erection, as compared with the re-erection of the timber bridge, considering the perishable nature of the latter?

Railways were designed especially for the carriage of goods, the passenger traffic, we are informed, being more a development of the system than an anticipation of the promoters. The first stations at which passengers were booked were but poor indexes of what they have become; they were booking offices literally, where the passenger's name was written on the ticket, and a counterfoil kept by the clerk. These stations were soon superseded by others, with platforms adjacent to main lines, which have, in their turn, given place to others at principal junctions and centres of greatest traffic, having platform sidings and slip roads for working and marshalling the trains, without impeding the through traffic on the main line.

ORIGINAL ROADS.

When the Act for the Stockton and Darlington Railway was applied for, the promoters contemplated a wooden tramway, but so thoroughly was the engineer convinced of the value of wrought iron for permanent ways, that he recommended the use of that material, though he was interested in a patent for cast-iron rails, taken out in conjunction with a Mr. Losh, in 1816.

The engineer was persuaded of the immense superiority of wrought iron, from the fact that at Killingworth, Swedish bars nailed to wooden sleepers had formed a durable permanent way for a period of fourteen years, under the heavy coal traffic of the district; when, in similar positions, cast-iron rails were constantly giving way. In consequence of the experience gained at Killingworth, the rails ultimately adopted and laid down were of wrought iron, and called "Berkinshaw's Patent Fish-bellied Rails," which were introduced by the patentee in the year 1820. They weighed 28 lbs. per yard, were 2 in. in depth at points of support, where they rested on the chairs, and $3\frac{1}{4}$ in. in the middle or bellied part; they were $2\frac{1}{4}$ in. broad across the top, and $\frac{3}{4}$ in. in thickness of upper table.

The Liverpool and Manchester Line, which was opened in 1830, was laid by the same engineer, with a similar class of road; but the rails were of heavier and stronger sections. The rails were 15 ft. long, fish-bellied, weighing 40 lbs. per yard; the bearings or points of support were placed every yard. The rails were the same breadth of top table as those used in the

Stockton and Darlington Road, but $\frac{1}{4}$ of an inch thicker; the web was $\frac{3}{4}$ in. thick, and the bottom flange 1 in. wide; the depth on chairs was $2\frac{1}{2}$ in., and at middle or half way between the bearings $3\frac{3}{4}$ in.; the chairs used were of cast iron, 9 in. long and 5 in. wide, and weighed about 15 lbs. each; they had two spike-holes and a groove on one side for an iron key to secure the rail. The joint-chair differed from the middles in having a key on each side.

The Grand Junction Line, which extended from Newton to Birmingham, and the London and Birmingham Railways, were early laid with the double table parallel rail. In a paper read before the Inventors' Institute, by Mr. Richardson, we are informed that Messrs. Stephenson and Locke were the inventors of this class of road; the rails were much stronger than the old fish-bellied ones, and they were secured to cast-iron chairs by a wood key. The author may here remark that after having seen and heard of scores of methods for fastening rails into chairs, such as by means of wrought and cast-iron keys or wedges, driven into the chairs, horizontally and vertically; cast-iron balls, forced against the rails by wrought-iron wedges, and wrought-iron screws passing under or through the rail, as well as merely staying it in iron chair by side contact; no rail fastener has yet, in his opinion, been able satisfactorily to supersede the wood key.

Locke's permanent way, as first put down, rested on stone blocks, with the exception of a few embankments where great subsidence was expected, at which places wood sleepers were used, and though laid down without the expectation, they developed qualities superior to the blocks, which soon caused them to be used throughout, when relaying was done. In some cases before the rails were worn out, the blocks have been removed and sleepers substituted, as it was found that the blocks under the heavy and increasing traffic began to tilt, and had to be stayed by, instead of staying, the rails, thereby causing great difficulty in preventing the rails from becoming twisted and out of line, which made the wheel flanges come alternately in contact with the outside and inside of rail.

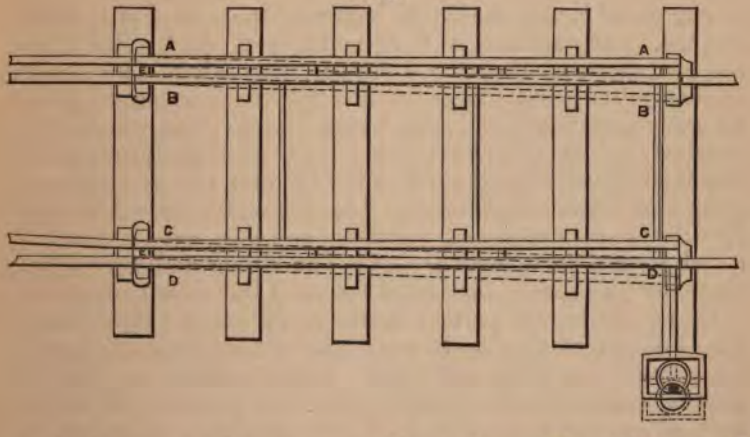
Another objection to these blocks consists in the tendency of the chairs to wear down into them, and the difficulty, when such was the case, of fastening the chair, which would loosen from the blocks, the road being thus thrown out of gauge. This class of road was deficient in elasticity and the power of distributing undue strains; the rails having to bear the full brunt of any extra friction from passing loads, produced by unevenness of running surface. The block road was laid down in a peculiar fashion, as compared with modern practice. The

blocks were first drilled to receive two wood ferrules, into which the spikes for fastening the chairs were driven. The chairs sometimes had a felt or other elastic packing.

Height and direction pegs having been driven into the ballast, a short piece of rail was securely keyed into each chair for a threefold object, namely—To take the height and direction of the blocks, which were to be laid down from the pegs, and to enable the blocks to be readily secured by means of a chain to a lever about 30 feet long, which rested on a tripod fulcrum, at a point about the height of a man's head from the ground, and about 3 feet from the end of lever. A solid bearing was obtained for the block by the lever-man depressing the long end of his lever and then suddenly raising it, thereby bringing the block down with a jerk. The process was repeated until sufficient blocks were bedded, when the short pieces of rail were taken out and the permanent rails keyed in their places. The manner of setting the blocks to the opposite rail was similar, excepting that the height and gauge were taken from the rails already laid down.

The author has not seen any specimens of the switches and crossings used on the first railways; but he is informed, by old platelayers, that the crossings were cast iron, and that the switches resembled those now in use by contractors in their temporary roads. The most primitive contrivance for effecting the movement of a carriage from one line of rails to another is shown at Fig. 1. It consisted of four rails, A, B, C, D,

FIG. 1.

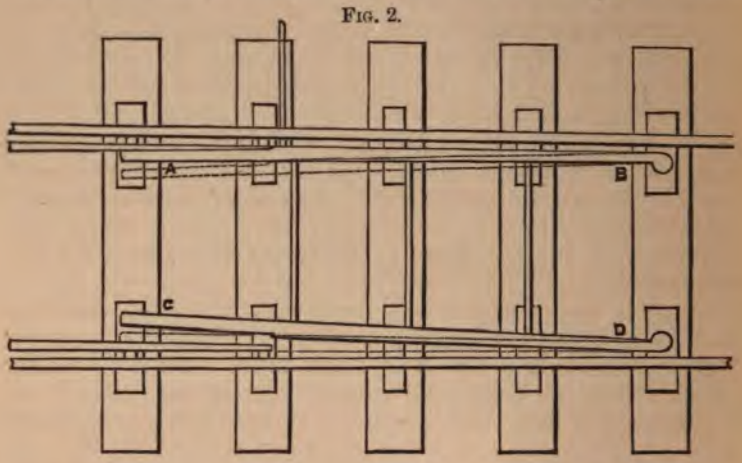


attached at one end to two movable castings, E F, which rested half-way on a movable cast-iron chair; the ends of the four rails

of the main line and branch occupying the other half of the chair. The castings were prevented from slipping off by means of pins, which formed the centres of small segments, in which the other ends of movable rails oscillated. Strong distance pins, and rods $1\frac{3}{4}$ inch diameter, were secured to keep the rails rigidly apart. These movable rail switches were worked by means of a rod, attached to an eccentric, which was actuated by a vertical arm. The strong and dotted lines show the two positions of the switches.

Another form of antique switch is shown at Fig. 2. This

FIG. 2.

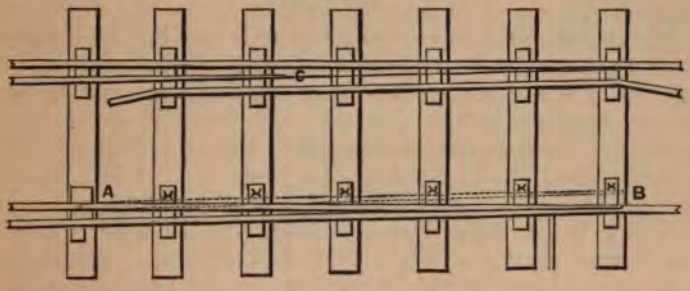


arrangement is remarkable, in being the reverse of our modern method. The outside rails were continuous, and the inside rails stopped short, on the second sleeper, from what is now called the heel of the switch; these interior rails were pointed and placed to gauge, with the opposite outside rails. The wheels were checked on to the right road, from the outside of the tyre flange, by means of movable guide rails, A B, C D, and not, as at present, guided from the running side. The guide rails were kept apart by distance pins of strong scantling, and they were actuated by a rod worked in a lever frame. The strong and dotted lines show the guide rails when fixed for main line and branch.

One of the next important variations in this part of permanent way is shown at Fig. 3. It was made by Sir Charles Fox, when he brought out his patent safety switch, which was the first approximation to the arrangement now in use. In its first application, the fast point at C with the fixed guide rail was reta[illegible] one side, and the patent switch, A B, was placed on the [illegible] The point at B was blunt, and in order to make it

lineable when the rails stood as shown in strong lines, it was notched back into the side rail, and when the switch was being

FIG. 3.



run over its width, placed it in gauge with the opposite outside rail. When, however, the fast point was being used, the switch acted as a check in that direction, the jaws of chairs in which it worked being the necessary width apart. The switch was worked by a rod and lever. The two positions are shown in strong and dotted lines.

It was an easy transition from the single to the double switches; these were at first made of unequal length, the side rail against the short switch being bent, instead of notched. As the notched side rail would have caused derailment without the opposite guide rail, which could not be used when the switches were equal in length, the under-side top table of the rail was slightly rebated, and the switches housed below. The rebating was subsequently dispensed with, and the switches were cut to the contour of the side rail. The objection to this method of fitting the switch became apparent when the traffic increased, and for some years it has been found preferable, on our best-managed railways, to cut the switches straight down, at their points of contact with the side rails, the point being hidden by a slight bend or shoulder. The alteration in the contour of these rails which takes place under heavy traffic is not so likely to prevent switches thus constructed closing up. The author has taken out a steel side rail, where the depression of the inner edge of the top flange has been considerable, amounting to ¼ inch below the original contour, when rolled, and in these cases it is apparent that had the web of the switch been shaped to house below a new rail, it would certainly have stood out, and have led to the wheel flanges striking. To illustrate the point still further, it not unfrequently happens that at branch line junctions, one of the switches is used considerably, and the other but slightly. Suppose a branch line leads off to

the right, the main line traffic preponderating would cause the greatest wear to take place on its switch and side rail, with a consequent depression of the latter, and when the branch switch came to be closed it might fail to go under, or in doing so get crushed.

The switch chairs have to accomplish a double object, namely, to stay the side rail and to form a slide for the switch. The staying of the side rail has been accomplished in two ways; namely, by a small inner jaw with a wood key outside, and by bolts and cotters. The former method has been discontinued, as it necessitated the cutting of a recess in the rail, with the contingency of the edges of this recess catching against the chair jaw, in the event of sleeper becoming displaced. Another reason was, that the switch was thus weakened at the point of support. The bolts and cotters are not much used in the intermediate chairs, as the switch and outer jaw are practically sufficient to stay the side rail where strong rail sections are used.

Points have been constructed with one switch slightly in advance of the other. In a straight road this arrangement is objectionable, owing to excess of gauge at the point of the short switch. But the author considers that it may be used with advantage in cramped situations in goods yards, where switches are required to lead out to the inside of short radius curves, as it enables the check rail to be continued past the long point, thus frequently preventing delay by the derailment of wagons when shunting.

The general shape of crossings has not undergone so much alteration as that of points and switches. The author has seen some very old crossings, similar in general outline to those in present use, consisting of V's wing rails and checks. The greatest improvements have been made in the shape of crossing chairs and the method of securing the different parts together.

The author observed, that the crossing leading on to the fast-points shown in Fig. 2 is similar in some of its chair fastenings to those used in the heel chair of the movable rail switches. The method of fastening was by means of screws, as shown at A B, in Fig. 4; the screw to chair B served the double purpose of staying the wing rail and securing the point of the V. Another method of accomplishing this object was by means of crossing keys or wedges on each side, as shown at C, Fig. 4; but, as these keys were liable to become loose, especially in dry weather, they were superseded by iron distance ferrules, with bolts passing through them as at D, Fig. 4; the bolts being fastened with nuts or cotters against the outside of chair jaw.

A few moments' reflection will show how much safer our

modern built-up crossing is, with blocks cast on the chair base, which take secure hold of the V, in comparison with these ferrules, keys, or screws, which would be sure to give way under present traffic. The author has seen in use a form of cast-iron block chair for crossings, resting on three sleepers with a groove for the rails forming the V, and with jaws cast on, for securing the wing rails. But the advantage of this arrangement is questionable, as extra labour would be required in renewing, before the rail could be drawn out of chair, and from the fact that if a wing-rail jaw broke off, the casting would be useless, the economy of this arrangement is more than doubtful. Of cast block crossings there are numerous sorts manufactured, both reversible and single-faced, and with the ends of the castings so formed as to adapt them to fished rails.

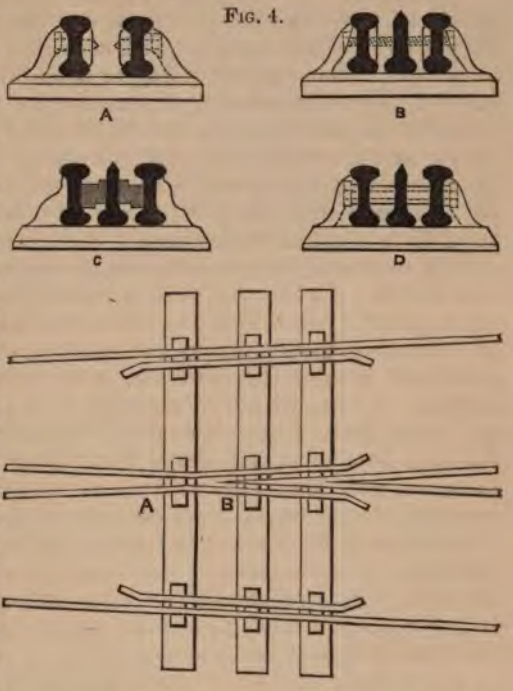


Fig. 4.

The author considers that one of the leading points to be attended to in a crossing is fixity of the V, which, in a facing crossing, must be well covered by the wing-rail shoulder. As the wear upon the different parts of a crossing is seldom uniform, it is very desirable, in designing them, to bear this fact in mind, so that the parts of greatest wear can be renewed and exchanged without having to reject the whole as useless. This appears to be one of the especial advantages of the built-up crossing, or those constructed out of rails. If the cranks in the wing rails of this kind of crossing are made to the same angles at both ends, and drilled, they may be turned ends about, and when worn out in that position they may be used for checks. Thus the wing rails may be used in six positions where the crossing has a long lead.

FIRST SIGNALS.

The signalling of trains at junctions, stations, and other points of possible obstruction on our early railways was, to a large extent, given by hand, and consisted of various evolutions of the red, green, and white flag, or hand lamp. But as traffic increased, these signals were superseded by posts, worked by signalmen; to these posts were affixed boards or discs of various shapes and sizes, both pierced and plain. The author is aware of upwards of thirty kinds of fixed signals, some capable of being turned with the post, others by means of a rod attached to it, in a vertical or horizontal direction, front or edgeways, and by means of the colour or shape, indicating the state of the line ahead. As the proper use of a signal is to make certain signs agreed upon between persons at a distance, for the purpose of conveying instantaneous information, orders, &c., it is to be regretted that a standard shape of railway signal was not adopted at first, with the sanction of the Board of Trade, for use on all lines. But as it could hardly have been expected that the best form of signal would have been hit upon in the first instance, now that the semaphore, which we think the best signal, is so generally used on all new lines, it is to be hoped that form will be adopted in renewals of railway signals of other patterns. The switches at junctions and sidings, as already intimated, were worked, in the first instance, by levers closely adjacent, for it would almost be impossible to concentrate the levers working the points shown in Figs. 1 and 2, the strain being so great upon the rod which actuated them. But soon after the switch came into general use, Messrs. Stevens, of London, invented and patented a method for bringing the various levers into a frame, to be worked by the man in charge of the signals.

This was a step in the right direction, because it placed under the charge of one man what formerly had to be effected by two or three. Still it was not perfect, and differed materially from the best practice of the present time. Its weak point consisted in trusting to human fallibility, as the man in charge might make a mistake—"*errare humanum est*"—and lower his signals when his points were wrong, or he might lower opposing signals. Although concentration was a great improvement upon the scattered point-levers worked away from signals, it required to be still further improved, so that the various movements of the levers, either for the purpose of lowering the signals or opening the points, should be made dependent one upon the other, which [illegible] omplished in an invention for interlocking the levers [illegible] s and signals, brought out by Mr. Saxby, and pate[illegible] e year 1856. It is proposed to explain the

various mechanical contrivances for accomplishing this arrangement in the second division of this paper.

The author has endeavoured to give a short sketch of the first division of this important subject, and to show the effects of time and the increase of traffic on original works, and how they have been strengthened and enlarged, to meet the requirements of to-day, also to describe, as far as his experience goes, and from any trustworthy information he could obtain, the kind of permanent way originally laid down, and how it has been altered and strengthened, as well as the means in use for signaling the traffic. He now comes to consider a more important part of the subject, not historical, but practical, namely, the means of maintaining railways with existing materials, and how to dispose of them to the best advantage, and with the least expenditure of labour.

MAINTENANCE OF WORKS.

On looking at a longitudinal section of any railway, it will be observed that the cuttings about equal the embankments. The object of that arrangement is apparent, namely, to save the purchase of land, either to obtain or to deposit extra material for earthworks. In a line, say 50 miles in extent, the formation level of the railway in cuttings will, of course, be below some of the various descriptions of clay, marl, gravel, or sand, characteristic of the district in which it has been formed. The materials taken out of the cuttings have been deposited in adjacent embankments, and unless in each case the earthworks have been trimmed or sloped to a batter, flatter than the angle of rest, they will come down in slips and ditch up the ballast in the cuttings, or let down the road on embankments. In both cases these slips will render maintenance expensive and troublesome.

Each slip has specialities which require dealing with separately, but generally they resolve themselves into two classes, namely, those where the natural strata have been left unsupported, in cuttings at a less angle than that of rest, and may have been set on the move by non-intercepted land drains or springs; and the slips in embankments, often consequent upon unusual drought, which cracks the surface, and if succeeded by heavy rains, will give opportunity for the percolation of rainfall, which, as nature's great leveller, is the prime mover of most slips. The author has successfully dealt with new slips, and stopped their further progress in cuttings, by digging a surface drain immediately above the slip to catch the rainfall that would otherwise find its way in, and at the same time

laying a drain pipe for the side ditch, as well as forming a good footing of the best available materials.

In cases where the slip is clay, and has become, as it were, tempered through being cast back, he has stopped its further progress by digging trenches at intervals into it, at right angles to the line, wider at foot than at top, with steps in solid ground below the slip. These trenches he has afterwards filled up with gravel, which, having been well rammed, sucks up the water, and with a good foothold below the formation level, acts like a buttress against the slip. This operation is, of course, best accomplished in a dry season. If land springs are found, it is preferable to catch and lead away the water in wooden troughs on props, to using pipes below the surface, which are liable to derangement and leakage through subsidence. It is also advisable to remove as little as possible of the slip material in cuttings where it can be kept tolerably dry by any of these processes, or others that might be enumerated, but if it is absolutely necessary to remove a slip, the hollow should be filled up to a safe batter, to prevent a set further back, and the purchase of more land.

With regard to slight embankment slips, the author prefers the driest and lightest material possible, such as ashes, for lifting the road, after subsidence has taken place; but in bad cases, it is found to be the cheapest way in the end to weight them with gravel, which will form an embankment within down to the solid ground. He has had occasion to try this method on a slip in a 20-feet embankment, which had recently been widened over an old slip, and as the new embankment remained good in other places, it was considered to be the best to weight down the old slip, which was accordingly done with gravel; it has hence resulted that there has been no more trouble with the place since, and the line has stood well. Not much faith can be placed in the use of piles in either cutting or embankment slips, as the act of driving them shakes the embankment and depresses the slip, and unless special circumstances arise, the author would not use them.

In the design and composition of our railway fences, engineers followed in the footsteps of their predecessors, who had constructed our canal navigation and roads. Judging by the development of the former class of fencing in the height and width, as compared with the fencing to our roads and canals, we do not need to be told what a much more important duty it is required to perform. Consider the different character of the routes the fencing is intended to protect. In the case of the roads, what matters it if a bullock or a horse does get over fence, or a sheep or lamb scramble through? The injury

is generally merely to the fence or beast itself, and the loss to its owner; the case would be similar if it strayed on to the tow-path of a canal; but the circumstances are quite different when we consider our railway protection.

Experience has proved that it is a risky and expensive contingency for the proprietors and engineers of our railways if cattle stray through the fencing. Engineers know it, and it is the object of those with whom the author is acquainted to make the fences with which they have to do thoroughly impassable. A railway fencing should be strong enough to resist a horse or a bullock, yet thick enough at the bottom to keep out sheep and lambs, and high enough to deter anything from leaping over.

The author has failed to see the special advantages of a uniform adoption of quick-fencing on all our railways; its quick and vigorous growth depends upon many causes, such as suitable soil and weather, the absence of the ravages of fires in summer, and ground game in winter, which when they attack a fence are highly injurious, as rabbits burrow under the roots, and in hard seasons bite off the young shoots and bark of the principal stems. Sheep and lambs are specially injurious to quicks, as they nip the spring buds with particular avidity, and help to keep the bottoms of fencing thin. Lambs will occasionally scramble through openings, almost impassable after small undergrowth.

As to the absence of screen, if quicks were not grown by the side of our railways, what screen are they to any embankment above the height of six feet? In a deep cutting, the edges of the slope hide the view, at a little distance away. It is a fallacy to suppose that cattle will not become used to trains rushing by, and it is one which may be classed with others of the same school, which were promoted by the opponents of railways forty years ago. It may be ranked among the category of such opinions as the probability of birds falling down dead on flying over the railway, and the sombre hue and fatal pollution of the atmosphere which would be produced by the smoke from locomotives.

Judging from its universal application up to the present time on railways, quick-fencing is evidently considered to be a *sine quâ non.* The author has seen it struggling for existence through stony soils, and endeavouring to maintain an erect position in peaty land. From the time of its first planting it has to be protected for nine years by posts and rails, and, in a few places, by partial fencing for a year or two more. The quick-fencing is a fact on nearly all our railways, and by studying its nature and capabilities, the engineer must make it do its work as effectually as possible, and with the least expenditure of labour.

In the author's opinion quicks are often treated too tenderly; the quickset or hawthorn is a tree, and not a shrub, and it will generally grow up in one stem, if it is merely trimmed at the top, and in the process of time will become a succession of trees, with here and there a gap, caused by some sickly plant, whose nourishment has been absorbed by some more vigorous neighbour, instead of an interlaced barrier, thick at the bottom as well as at the top. To prevent the possibility of a thin undergrowth to quicks, the author would, in dealing with a young hedge, cut it down level with the ground after about twelve months' growth from first planting. Each root will then have taken well hold of the soil, and the stumps will, the next year, throw up a three or four fold array of stems, in place of every one cut down. This will ensure a thick undergrowth; it should then be allowed to grow about a foot per annum, the soft end feathers of each branch should be cut off, causing them the next year to throw out additional stems. When it has attained the required height it may be left to increase in thickness.

Cutting and laying is a good means, when properly done, by which an old, thin, and straggling hedge can be thickened, and made a more complete protection to the road, but before the operation is effected, the quicks must be left to grow a season. Various opinions are entertained as to the advisability of laying railway quick-fence, but in cases of this kind the author considers the laid preferable to the unlaid fence, as, when beasts press against the former, they have the resistance of a series of stumps, interlaced boughs, and young shoots, whereas in the latter a slight gap can readily be bent open wider.

There are two or three ways of laying a fence.

1st. The quicks may be nicked near the ground and leaned a little outwards, to give the new shoots an opportunity to grow unimpeded.

2nd. Where the quicks are in double row, they may be crossed, the outside row inclined one way and the inside row the other. One of the best quick-fences in this country, that from London to Birmingham, was cut and laid somewhat after this fashion more than twenty years ago, excepting that the quicks were trimmed freely, and the fence presented the appearance of a sort of rustic hurdle. Underneath the vigorous growth of this fencing may now be discerned the old layers.

3rd. One row in a double fence is sometimes cut off, which will throw up vigorous shoots, the other row being the only one laid.

The laid fencing may either be strengthened vertically, by means of live stakes left standing, or by others cut and driven in. The former method is sometimes objectionable, as it pro-

duces knots of stems which may interfere with cutting in after years. The best time for cutting fences is just before the leaves fall, at the end of August or the beginning of September. No injury can then be done in cutting the young wood, which will crop easily, the fibres not being hardened by the winter. The state of the twigs for cutting is an important item in expeditiously getting through with this work. As a good strong quick-fence will girth four and a half yards, it gives a superficial area of 7920 yards of quick-cutting per mile.

Quick-fencing requires attention in the few months of late autumn or early winter, which period is of the utmost importance to the permanent way, in order to get the road in a fit state to stand the winter. At this period the surface ballast drains require looking to; they should be well opened out underneath the rails, the ballast should be boxed up, the side ditches in cuttings should be cleaned out, and the margins of formations ought to be trimmed and the surface generally placed in such a shape as to ensure the speedy flow of rainfall. Under these circumstances it is evident that quick-fencing is somewhat inopportune in its requisitions on the time of the platelayer, whose first duty is to attend to the road, as his name implies. It may be said in defence of quick-fences, that they can be cut and dug in frosty weather, when nothing can be done to the road. But take the case of a mild winter—either the fences must be neglected or extra men must be put on to do the work, or on the other hand, if the existing staff is sufficient, the line is overdone with labour.

Stone walls are extensively used for the protection of railway property in the hilly districts of the Northern Counties, Wales, and Scotland. These fences are built of dry rubble on a shallow foundation, about one foot below ground line. They are usually about 21 inches wide at ground line, and 15 inches at the top; they rise to a height of 4 feet 3 inches, to the coping, which is made round at the top and set in mortar; it increases the height to 5 feet. As a preventive against sheep getting over, the author is informed that there is a good arrangement of coping in use in Scotland, the stones forming it being rough, and alternately projecting over the face of the wall. These stone fences are the most effectual in the places where they are erected, as quicks would not grow to sufficient size if planted, and the prongs of iron fencing could not be fixed owing to boulders, or the proximity of rock to surface. Not much expenditure is required in the maintenance of stone-wall fencing if it is well built at first. The chief causes of failure are the giving way of foundations through land slips, as well as from insufficient bond; the former contingency is common to all

fencing of whatever kind, and the latter may be guarded against by careful supervision whilst the work is in hand.

The author considers that iron fencing, if properly constructed and well fixed, will compare favourably with any other kind of fencing for new lines, in those localities where quicks are now grown, both in the facilities afforded for repairs, and in the cost of after maintenance. The saving effected by the use of iron fencing in the item of land, in places where it is rich and valuable, is worth noticing. If iron fencing is used for railways, when land slips occur either in cuttings or on embankments, the line can easily be protected, by refixing the iron fence around the outer edges of slips, in places where under similar circumstances quicks are completely disarranged, and would not grow if transplanted. The iron fencing should be erected for cuttings at the top, and close to edge of batter, except in places where open ditches or land drainage interception pipes are required, in which case the line of iron fencing should be erected beyond. Iron fencing to embankments would, of course, be placed at the boundary of the company's land, at the foot of slope, until the earthwork had become consolidated, and the slopes grassed over, when, if the slopes could be let profitably for sheep grazing or mowing, the fencing might be taken down and re-erected near the top of slope, sufficient space being left for maintenance purposes, such as opening out ballast and depositing materials for relaying and other purposes, as well as space for lorry when not used; extra space would be left at each under-bridge for platelayers' cabins, stacks of old sleepers, and rails.

The presence of good railway communication in our mining and manufacturing districts is a source of considerable advantage, both to the owner and the consumer of our mineral wealth. Railway communication affords good facilities, by means of sidings and branches, for the transit of coal and iron, and it places within easy reach of one another the centres of consumption and manufacture. Railways have opened districts which, but for their ramifications, could not have been worked with profit, or which would not have been accessible by means of canals. As it will not pay railway companies to purchase the minerals, to prevent their being got, and the line being undermined, for the protection of the ordinary works on a line of railway, it follows that, in proportion to the number and thickness of the seams of coal to be worked, so much more likely is the railway to be affected by getting them; and not the least important of the engineer's duties relates to keeping up the line at these places. In dealing with bridges over mining operatio[illegible] walls and arches crack, owing to direct subsidence, or [illegible] drawing effect of mining operations in the neigh-

bourhood, the wing walls have to be stayed and buttressed, the abutments raised with extra brickwork, and the girders raised to a higher level. The author finds it best, at places where subsidence is rapid, to have a strong timber wall-plate under the whole of the girders, instead of bed-stones, as it distributes the bearing and admits of wedging and packing with greater facility. Where, through lifting the permanent way, the arch-over-bridges become too low, the arches have to be cut away, the abutments raised, and the road carried by means of horizontal girders. The permanent way has to be kept constantly on the lift, but this is merely a question of engine power and labour, as there is usually an abundant supply of material in the cinder heaps of the district. If sleepers are used it is sometimes necessary, where the workings are shallow, to place baulks under the permanent way, in order to guard against crowning-in.

MAINTENANCE OF ROAD.

Before entering upon that portion of the subject which relates to the present practice of permanent way maintenance, it will be advisable for the author to describe a few of the different sorts of roads that have come under his notice. They may be divided into two general classes—The Longitudinal and the Cross Sleeper roads.

By the longitudinal class the author means all the permanent ways that take a continuous support for the rails from the ballast, either direct, as in Mr. Barlow's road, or with the intervention of timber longitudinals.

Continuous bearing is one of the principal advantages claimed for the class of road now under consideration by its advocates, and no doubt this quality would be of great importance, from an economical point of view, as it might admit of lighter scantlings of rails and timbers being used, if it could be repaired and drained with the same facilities as the cross-sleeper road. One of the most generally-used longitudinal roads, and the author believes the first of its class in this country, was that introduced by Mr. I. K. Brunel, on the Great Western Railway. It consisted of a hollow single-headed rail, secured to longitudinal timbers with bolts, and held to gauge by means of cross-ties. Between the longitudinal timbers and rails, to form packing for the latter, were placed strips of hard wood, with the grain at right angles to the longitudinal timber; these strips were for the purpose of preventing indentation. As this system of permanent way was originally designed for the broad gauge, it is hardly an index of what Brunel would have recommended for a

narrow-gauge railway, if the former had happily never been thought of.

Another form of longitudinal permanent way has been introduced by Mr. Seaton. It consists of three principal parts; rail, longitudinal, and cross-ties. The most noticeable feature about it is the rail, which roughly resembles in cross-section a rolled ridge tile; it is supported on a longitudinal timber, triangular in section, cut to that shape by bisecting a baulk diagonally. The rails are secured to this timber, which is placed on its broadest base, with screws, and the rails are joined by means of a bed-plate; the longitudinal timbers rest on cross-ties, by means of which the road is maintained to gauge. In modern times we have an invention, consisting of a combination of timber and iron, which belongs to the class of longitudinal road. The author alludes to that invented by Mr. Featherstone Griffin.

Of iron longitudinal roads, we have that invented by Mr. W. H. Barlow, which combines rail and sleeper in one bar. The rails are very heavy, as might naturally be expected, to enable them to accomplish the double requirement; they are joined by means of a plate fitting the core of rail and bolted to it, the two rails are tied together, and maintained to gauge by means of wrought-iron cross-bolts. These rails take their bearings direct from the ballast.

Mr. Adams has designed and introduced a kind of longitudinal iron road, consisting of deep central rails, double or single faced, to which are attached angle-iron sleepers on each side of webs by bolts every 2½ feet; the rails are tied together by tie-rods about 5 feet apart, and they break joint with the angle-iron sleepers.

A kind of permanent way, or rather sleeper, has been introduced by Mr. Greaves, in shape like a flanged cast-iron pot, resting with the concave side on the ballast, and with two jaws cast on the convex side to receive the rail.

Other kinds of permanent way, the author notices, are frequently being invented, patented, and submitted to the judgment of the profession; they are intended to meet the requirements of light and heavy traffic, and fast or slow speeds, or the peculiar requirements of hot climates.

The permanent way that has been laid with greatest success in this country, and the most generally in use, is that introduced on the Grand Junction and London and Birmingham railways, called the cross-sleeper road. In the author's opinion, one of the first requisites in constructing permanent way is to ensure such an arrangement of its parts as not to interfere with the formation of surface grips and drains. The most direct

means of draining the surface of 6 feet and 4 feet spaces is, of course, by forming grips at right angles to the line of road, under the rails, and leading the water direct into the side ditches. But if this is done in a longitudinal road, it will necessitate the removal of the ballast from below the longitudinals to a considerable extent, and hence in proportion to the effectual surface drainage will be the diminution of one of the advantages,—namely, continuous support to the rail, which that class of road is supposed to possess. If, however, the formation of surface drains under the longitudinal road is neglected, the water will be left to percolate wholly or in part through the ballast, and either a superior class of ballast will be required, to absorb the excess of moisture, or the road will work and accelerate friction in the different parts of which it is composed.

The rail sections used in this country have been almost as numerous as the different lines and branches which help to make up our railway system, and as our large companies to a considerable extent have been made up of these individual units, the maintenance engineer has to deal with numerous varieties of rail sections. In addition to those already described the principal varieties that have been adopted are as follows:—

1st. The reversible double-headed rail.

2nd. The double-headed rail with only one running face.

3rd. The single-headed rail.

4th. The flat-bottomed section, known as Vignoles' rail; and

5th. The bridge section, or contractors' rail.

One of the most noteworthy applications of the Vignoles' pattern is that in use on the Metropolitan District Railway introduced by the engineers, Mr. J. Fowler and Mr. T. Marr Johnson, in their permanent way; which, we are informed, was especially designed to meet the requirements of the heavy traffic and frequent trains on that line. The rails are of steel, and weigh 84 lbs. per yard, the top table is $2\frac{1}{2}$ inches wide, and a little thicker than a rail of similar weight, but double-faced; the bottom flange is $6\frac{3}{8}$ inches wide, $\frac{21}{32}$ inch thick at root, and $\frac{3}{8}$ inch thick at edge of flange; the web is $\frac{11}{16}$ inch thick; the rails are of various lengths, but principally 24 feet long; the middle bearings being about 2 feet $8\frac{1}{2}$ inches, and the joints 1 foot $10\frac{1}{16}$ inches. The cant of rail, which is 1 in 20, is obtained by cutting the sleeper under the inner edge of rail. The joints are, of course, fished; the fish-plates are 15 inches long, and as the sleepers are only 12 inches apart at joints, the plates have a bearing of $1\frac{1}{2}$ inch on each joint sleeper, which will strengthen that part of the road considerably, and tend to prevent friction. The rails rest with a direct bearing on the

sleepers, and are secured by two fang-bolts at each bearing; these bolts have Whitworth threads, pitch 10 threads to the inch. The other descriptions of rail sections appear in numerous varieties, with strong and light webs, and thick or thin running faces, as well as of different weights, and they rest in chairs equally numerous in pattern.

As the branch lines, which go to make up our railway systems, required repairs, it became necessary to adopt a standard type of rail section, which, of course, enabled companies having a large consumption to get permanent way materials at greatly reduced prices, owing to competition induced by large orders. On the score of economy in the maintenance of permanent way, the author considers it advisable to bring the materials to one type, to admit of the interchange of rails and chairs; and to effect this alteration to use the standard type when rails of other classes are required for repairs. It may be objected that this involves double labour, but an engineer will generally have an opportunity of selecting a road that wants re-sleepering where rails or chairs are required, and this will enable him to do the two operations at once, *i. e.* obtain rails and chairs of required type, and renew his sleepers. This arrangement will certainly be cheaper than ordering rolls to be kept merely for the manufacture of all the particular kinds of rails on the lines under his charge, which almost amounts to giving a monopoly of the various shapes of rails to the rail-makers who own the rolls. The selection of this standard type of permanent way materials is of primary importance, and it should not, on any account, be deviated from except for the most cogent reasons.

The qualities absolutely requisite in designing permanent way are, besides drainage, which has already been alluded to, facility for removing and repairing defective parts with the least possible derangement or disturbance of parts adjoining. For instance, the removal and turning of rails should be effected without disturbing the chair bed, and the removal of the chair should be effected without displacement of the rail. The greatest variety of schemes have been introduced and patented, for all sorts of rails, chairs, and fastenings, and this fact should cause all those in charge of permanent way to be extremely careful in selecting specimens for trial. As samples, the author may here remark, that he has seen and heard of schemes for fastening the rail in the chair which required a groove to be cut in bottom table of a reversible rail. This, of course, would be to the durability of the rail when turned. Also, keyless 's that had to be slipped on to the rail from one end, and , in the event of a spike-hole breaking, would require the

removal of all intervening chairs to get another chair on. This contingency, by-the-by, is no uncommon occurrence in the event of sleeper not being prised up against chair during the final taps with the hammer. Joints cast on to the rails with iron run from movable cupolas have been proposed and tried; but when a joint worked loose, or a rail required turning, these castings had to be broken in order to liberate a defective rail; thus proving the total impracticability of maintaining that arrangement of joint. A road that will require a minimum of repairs, and that will afford the greatest facilities for carrying out those that are absolutely necessary, is of great value.

The following points are of importance in considering a new kind of permanent way:—

How will the different parts be affected with eight or ten years' wear, and can they be repaired with good old materials of similar patterns?

Will the chair fastener be injuriously affected when the chair wears into the sleeper, and in the case of fang-bolts being used, will there be sufficient thread to keep them tight? The possibility of nuts becoming unthreaded is sufficient to condemn this sort of fastener in some ballast, as the road could never be made to stand if the sleepers had to be undermined to replace the nut.

As regards the rail fastener, if wood keys are used, will they fit properly when the rail has become indented into chair, or will the reduction in depth between the top of the rail and the rail bed require a corresponding reduction in the size of the key to make a true fit?

The author is of opinion that in driving a new wood key to replace an old one in certain shapes of chairs, the rail is uplifted to something like its original position in the chair, and leaves a cavity between the bottom flange of rail and chair bed, which accelerates friction and further indentation of the rail. In case of inside keying, it is necessary to consider whether sufficient space is allowed vertically between the surface of the rail and the top of the key, to prevent old wheel flanges dragging out the latter when the brakes are applied. Also in case of sleepers, will they be injuriously affected and incised by the shape of the chair base, or the chair fastening? The former should be so shaped that the life of the sleeper will be coincident with the time during which the wood continues sound, and the latter should be so arranged as not to accelerate decay by splitting the timber. The maintenance engineer has to keep his road up to a high standard, to suit the requirements of a greatly increasing traffic. In treating of maintenance operations, the following remarks will have reference solely to the cross-sleeper

permanent way, as that is the class of road which most intimately concerns us, being the style most prevalent in this country, and also, the author observes, that which is gradually superseding other descriptions when relaying operations are carried out.

The question of steel and iron rails has been so thoroughly discussed in all its bearings, whether scientific or economical, since their experimental introduction at some of the points of greatest wear on our leading railways, that the author can merely direct attention to these early experiments, and endeavour to substantiate the deductions of the time by the experience resulting from the trial of steel rails, in the everyday wear and tear of railway maintenance. In the Appendix the author gives a table (A) showing the comparative wear of steel and iron rails under similar traffic, from which it will be observed that the steel rails have a considerable advantage over the iron rails for the time during which the comparison can be made. The cause of failure of the vast majority of iron rails is not from the wearing down of the running faces, consequent upon the traffic; but from laminations, or spreading out of the fibres of the iron, resulting from local defects in the welding. In steel we have a metal with thoroughly homogeneous and elastic qualities, which has proved itself fully equal to sustain the peculiar requirements of the wear produced by rolling loads, as well as to bear without crushing the effects of impact.

In the discussion that took place after Mr. C. P. Sandberg's paper on the manufacture and wear of rails, read before the Institute of Civil Engineers, March 3, 1868, Mr. E. Williams ably summarized the advantages of Bessemer steel rails, which, he said, "would wear well, not so much because they were made of steel, as that they were rolled from solid ingots. He thought that what were usually called the best iron rails—rails for which an extra price was paid, and which were carefully watched during their manufacture—were really the worst rails, for the reason that the iron composing them had to be worked over and over again, and after each working it welded with greater difficulty than before. No kind of iron welded so easily as puddled bars."

Sir Charles Fox thought, that "an iron rail when manufactured, even in the best way, was little more than a bundle of rods; and the top slab might be compared to a piece of hoop iron lying on an anvil (the body of the rail), when a heavy locomotive passing over, it acted as a sledge hammer."

The author considers that the guarantee system with iron rails is the best. Let the engineer ascertain the tonnage passing over the part of the road where he proposes to use the rails,

and require a guarantee accordingly, and as the stability of the sleeper, and through it the life of the rail, materially depend upon the ballast and formation, the quality of the former and the state of the latter should be taken into consideration.

As the quality of iron rails depends as much upon their manufacture as upon the iron used, the interests of the contractors and company are identical, the object being to obtain an article to stand the guarantee, for it cannot pay the contractor to supply two rails at the price of one, nor the company to insert two rails in the road where the life of one should be of equal duration.

After obtaining a good article the duties of the maintenance engineer may be said to commence, and as steel rails will undoubtedly come to be the material of the future on all our main lines, and, as traffic increases, on some of our branches, the following remarks apply more particularly to them. Efforts should be made to get the other parts of permanent way to the highest perfection, so as to obtain the greatest amount of wear out of steel rails, which at present prices bear a proportion of 1·0 to ·47 to the total of all the other articles required in a given length of permanent way. This can only be done by making the road of uniform strength, or as much like a continuous rail as possible, and in a double-faced rail permanent way, by supporting the rail from a point other than the bottom flange, so as to dispense with indentations of chair, which are a fertile source of injury to the rails themselves as well as to the sleepers and rolling stock.

Before the invention of the fish-plate, efforts were made to obtain the first requirement, *i.e.* a level joint, by making the joint-sleeper of wider base and the joint-chair of larger area than the middles. This arrangement of joint-chair caused a large sacrifice of rails through the drop that took place from one rail to the other after a few years' wear, the great friction through insecure fastening, and the crushing effects produced at the ends of the rails.

The introduction of the valuable invention of fishing the joints has produced a considerable saving in labour and materials, as the rail ends have thereby been preserved, thus reducing the expenditure for cutting rails and altering the bearings of sleepers. The author considers that the cost of fishing any line pays for itself in a rail's life, through these items alone. He has seen a combination of the fish-plate and joint-chair arranged to unite the advantages of the two, *i.e.* for the purpose of keeping the joint level and securing the ends of the rails. The former operation was sought to be accomplished by placing a chair immediately below the joint, and the latter by using the

ordinary fish-plates, two of the bolts passing through the joint-chair-jaw. The advantage this system possesses over the slung fish-joint is more than doubtful, as it cannot under heavy traffic remedy the chief evil of the joint-chair, namely, its rocking movement consequent upon the two rails resting upon one base.

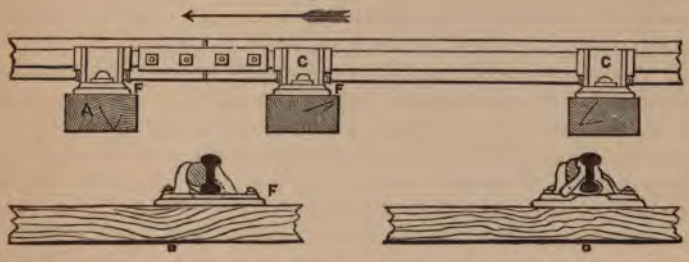
An experiment has been tried by the author with two similar chairs and slung-joint, the outer bolts of plate being secured to the chair-jaw. This arrangement (intended to supersede the split or bracket chair-joint) differs from it in having the base solid, a *sine quâ non* in all permanent way chairs. There is also no excessive strain on the bolts as in split joint-chairs. The author's experience leads him to consider this arrangement a good substitute for split joints, where the latter have been tried without success, and certainly better than moving the joint-sleepers and lengthening the bearings. Other arrangements have been tried for strengthening the joints of rails, and little further can now be done until the bearing of joint-sleepers on the ballast is increased. We have failed to make the rail as strong at that point with the ordinary fish-plate as it is between the middle bearings, there being a constant tendency on all slung-joints the author has seen for the sleepers at that point to work lower than the others, and for the rails to become hog-backed, involving, where the ballast is hard worn, great labour in packing these sleepers to maintain a level surface.

The strength of the road is its weakest point; this point is also that at which the greatest wear and tear occur, and though the joint-sleepers are usually placed closer together than the middles, it is clear from what has been stated that we have not yet made up for the breach of continuity in the metals, and until the joint bearings are made of equal strength to the middles, the minimum of labour on maintenance can never be arrived at even when steel rails are used. The length of joint-bearings should bear a proportion of about two to three to the middle bearings.

As the sleeper A, see Fig. 5 (in which the arrow denotes the direction of the traffic), always shows signs of greatest strain and produces a slight lipping tendency of the near over the far rail, it has obtained the name of the "dropping" sleeper. To obviate this, and to make it equal in strength to the others, it might be increased in area of base from 10 inches by 9 feet, its present size, to 11 inches by 9 feet and $5\frac{1}{2}$ inches deep. This arr ent would place the base half an inch lower than the o pers, and give it an area of $8\frac{1}{4}$ superficial feet, or 10 ore. The extra cost of these sleepers would soon be our and rails. Moreover, we have gone on increas-

ing the area of the chair base from 9 inches by 5 inches, as first in use on the Liverpool and Manchester line, to 14 inches by

FIG. 5.



7 inches in the present day, which is nearly double, without a corresponding increase in the tread of the sleeper.

Efforts have been made to strengthen the joints of rails by increasing the depth of fish-plate. One of the most noteworthy recent examples is that used by the engineer of the Festiniog Railway. This may be done with advantage when single-faced rails are used, as in the above-named line, but the author fails to see the probability of its successful application on double-headed rails, especially where iron ones are used, owing to the alterations in shape through lamination, which would prevent the fish-plates clipping accurately the bottom table of a reversible rail.

A source of friction at the joint is often produced by the loosening of bolts. Various efforts have been made to prevent this by altering the shape of the bolt itself, as well as by a great variety of washers. The following are a few kinds that have come under the author's notice:—

1st. Bolts of ordinary shape, passed through one fish-plate and rail, but without a nut, the opposite plate having to accomplish the double requirements of nut and fish-plate.

2nd. Bolts with threads at each end of different pitches, arranged so that they would tighten themselves on being turned into the plates by the gain of one thread upon the other.

3rd. Bolts with reduced shanks.

4th. Locked nuts; and

5th. Elastic washers, and washers made to secure nuts.

The author would be unwilling to supersede the ordinary bolt and nut in common use by any of these methods; he considers that a great deal depends upon the platelayer whether bolts or nuts work loose, and he insists upon the men under him being particularly careful to tighten up the bolts in a new road for the first week or two after relaying operations, as he finds

that if the thread gets set with the nut close up and the bolt tight, it is very unlikely to give further trouble in screwing up.

Smooth running of reversible rails may be improved by supporting the rail in the chair at a point other than the bottom flange. The author's attention has been particularly directed to this subject during the past eighteen months. In order to ascertain the positive saving that would be effected by accomplishing that object, and obviating the present tendency of rails to become indented by chairs, he has shown by Table B in the Appendix the comparative life of both faces of a reversible rail. He has found that as a rule the life of second rail-face was in an inverse ratio to that of the first face, owing to the deeper indentation produced by longer wear. This is a problem of absorbing interest at the present time, now that we have a metal of a homogeneous character for our rails.

Efforts are being made to reduce these indentations to a minimum by turning the rails periodically, and before the chair base has cut deeply into the rails. If frequently done this entails considerable labour in execution and more in repairs, owing to the rattle and vibration caused by the roughness of the running face. Where double-faced rails are periodically turned, a fraction of the line will always be rough, the denominator of the fraction being the number of years each face is used before it is turned. For instance, if the rails be turned every three, four, or six years, a third, fourth, or sixth of the road will ride rough during the time taken by the traffic to abrade the indentations.

These marks will, of course, accelerate the wear and tear of the running surfaces until the rail is again smooth, as may be observed by reference to Table B, for it is not probable that an iron rail which has stood well with one of its faces under traffic for eight, ten, or twelve years, will become worn out or crushed in as many months when turned *in situ*. Though the second face cannot be expected to wear as long as the first if the latter is worn out before the rail is turned, the author considers that if the cause of these indentations was removed, its life would approximate in duration nearer to the years than to the months given in the table, even after making allowance for the decrease in the strength of the road by the depreciation of the original sleepers, chairs, and fastenings, as well as for the extra wear caused by the general increase of traffic.

Engineers on one or two of the principal railways are removing as far as possible the probabilities of indentations by widening the chair base, and as the marks are produced by two causes—compression and incision—the former will, no doubt, be reduced by this arrangement; and the latter, caused by the sharp edge of a chair, can, of course, be prevented by rounding it off,

which the author is somewhat surprised has not been adopted. He has designed a chair, shown at B, Fig. 5, having the sharp edges of its base where it rests on the sleeper as well as the sharp edges of the surface supporting the rail rounded off. With this arrangement any indentations there may be either in the rail or sleeper, will be the result of direct compression, and traffic being equal, will be in inverse ratio to the width of bearing faces. A chair has been designed by the author for the purpose of preventing rail indentations; he proposes to use a loose outer jaw and wood key, as shown at C and D, Fig. 5. The rail is securely supported from the underside of the top table, and the outer jaw is so arranged that it will not become displaced during the temporary absence of the wood key. To remove the outer jaw it is necessary to raise the rail in the chair about a quarter of an inch after the wood key has been removed. Projections should be cast on to the outer jaw, which will necessitate its removal from above instead of from the side as in the case of the wood key. No friction takes place against the wood key owing to the intervention of the loose jaw, it would hence be more likely to retain its position. The base of the chair might be reduced in thickness if thought desirable, as the rail would be supported on it from two places, instead of at the middle only, as at present.

Rail indentations not only shorten the wear of road itself, but, by producing rough running, they considerably curtail the duration of the life of wheel tyres, journals, and axle-boxes of rolling stock; and unless first-class springs are used, they produce vibration and rattle in the carriages.

On a consideration of the relative merits of rails constructed for running on one or both faces, the author is inclined to favour the former, which he thinks will be the rail section of the future, even with the successful introduction of anti-rail indentation chairs. In any double-faced rail section there is a limit or line of safe abrasion to which the metal may be safely worn down, with the supports or bearings adapted to a new rail; if the wear is increased beyond that limit, the bearings or number of sleepers must be increased also. Why not, in the first instance, construct the rails with this surplus metal rolled all on one face, thus saving the necessity for all rail turning, with its attendant expense in labour, loss from removal of keys and spikes, and roughness of running?

As regards the distances apart of sleepers under steel rails, they should be arranged at first for reduced strength of rail, consequent upon reduction in depth and sectional area of flanges by traffic during the period of first sleeper life. When the road is re-sleepered an extra bearing can be put under. If the road

is lifted with extra ballast at the same time, there will be no objection to the re-arrangement of the sleepers, as they will all occupy new positions, and the rails will take a fresh bearing with uniform settlement.

The author considers that the double-faced steel rail may be turned with advantage two or three times during its life, in order to keep the wear and sectional areas of both top and bottom flanges equal, so as to ensure always the maximum of strength for given sectional areas. It is problematical in the present position of our experience of steel rails for permanent way, whether other advantages are to be gained by turning them, such as the preservation of elasticity by reversing the strains and alternating the running first on one table and then on the other. In the best practice the permanent way and rolling stock superintendents should work in unison, the one keeping his road in first-class order, to ensure smooth running, and the other his stock in the best condition, and so constructed as to absorb part of the stress from minor concussions in the springs. With the general introduction of steel rails, special lifting and sleepering operations will need to be more extensively carried out than at present.

Second only in importance to the design of the permanent way and the good quality of the materials used therein, are the kind and thickness of ballast on which these materials are bedded and boxed up. Ballast, like the other materials belonging to the permanent way of railways, will wear out in time; in other words, it will, by the action of the weather and traffic, as well as by the frequent overhaulings it receives during the operations of opening out, packing, and boxing up sleepers, cleaning grips, &c., become loamy and soft, and lose, by admixture with foreign substances, the strength necessary to support the road, which will gradually settle down and take a bearing nearer formation.

If the road in which iron rails are used is amply ballasted at first, with strong ballast, where its life is not more than six years' duration, the ballast will be sufficient to keep it up, provided a few extra wagons of ballast are added near the close of the term, for packing purposes and to replace that which has blown away. In other words, the general lifting of such a road at relaying is sufficient, and under these circumstances it is not advisable to interfere with the free running of trains, for the purpose of lifting a road which will so soon have to come out altogether. Circumstances will be otherwise with steel rails, as the ballast will be worn out long before the rails require renewing.

The qualities absolutely necessary in ballast for permanent

way are strength, dryness, and abundance. Without strength in the ballast, it will be difficult to keep the road level at weak places, as well as to pack low joints to stand for any length of time, and without dryness or good draining qualities, the ballast easily becomes surcharged with moisture, and will not speedily recover itself after rainfall. Ashes are good as ballast for their powers of absorbing moisture, and when they can be easily obtained and in abundant quantities, mixed with good gravel or clinkers, they make first-class ballast. But when used sparingly and alone, their porosity is fatal to their durability, as they speedily grind up under the sleepers in packing operations, and when in fine powder are little better than loam. Without an abundant supply of ballast the keys and sleepers cannot be kept covered, which in summer is very desirable, to prevent them becoming cracked or loose by the sun. Lifting operations can be best carried out by large gangs of men, say from 30 to 40, as while the work is in hand the strength of the road is affected, and trains have to be slackened, causing interference with traffic, which should, of course, be of as short duration as possible. In carrying out the work, the rails are lifted to heights driven in the ballast; the operation is carried on without unlinking the rails or unspiking the chairs, by means of levers placed under each joint. Every sleeper should be well packed at the ends under the rails as the work proceeds, and after two or three trains have brought the road to its bearing, they should be gone over again, the road made perfectly level, and the sleepers packed uniformly throughout. As the sleepers are exposed during lifting operations, the author has them carefully examined, which saves opening out again if that work is delayed till afterwards. The defective sleepers should be replaced, the chair fastenings made good, and the keys renewed or packed where loose. The ballast may then be filled in and the surface drains formed. As regards the number of these drains, the platelayer should be guided by the quality of the ballast and the state of formation, &c., but the author considers that there should be at least one through grip to 6 feet space under each length of rails; and as the strongest part may be placed between the 3rd and 4th sleeper, under a 21-ft. rail, there should also be a small grip for 4 ft. space between the 6th and 7th sleeper. This may be made to keep the joint-plates dry without weakening the dropping sleeper. The author considers it a better plan than placing the short grip under the joint, and if properly constructed, it will afford equal facilities for examining the bolts, nuts, and plates. The grips should each have openings in grass margins cut immediately opposite to drain down the embankments, or into

side ditches of cuttings. Ballast drainage, except in station-yards or under special circumstances, by means other than surface grips is a mistake. Short low places should be immediately lifted by the platelayer with his ordinary gang of men, as they are more detrimental to smooth running than long slacks. The supply of ballast depends in a great measure on the district through which the line runs, and unless land has been set aside for ballasting purposes when the line was made, the position of the ballast pit should be regulated, other things being equal, by facilities for obtaining land, safe access from line, and cheap working. Although excellent gravel for ballast is sometimes obtainable below the water-bearing strata, the author considers the use of sunk pits inadvisable, owing to the expense of pumping. If on a main line, it is advisable to get the ballast siding and pit at a telegraph signal station. The reason will be apparent, as it not only saves an extra signalman, but gives desirable facilities for working the ballast train.

On lines where the traffic is light, it sometimes becomes necessary to renew the sleepers before the rails are worn out, the former having decayed or become deeply indented by the chairs. No safe rule can be laid down as to the life of the sleeper, as it, of course, depends upon the quality of the timber used, the density of the ballast, and the state of the formation. Owing to the indentations in sleepers already alluded to, it is sometimes necessary to renew the sleepers; when this operation is performed, the road can be re-ballasted, put on a new bed, and its life much extended. The cause of failure of a large percentage of sleepers is splitting; the author considers that the shape of the chair base and position of the spike-holes have a great deal to do with it. The best form of chair base is rectilinear, with the edges rounded (see diagram No. 5 at F), to prevent as far as possible the incision of the wood, and wide enough to prevent hollow-packed sleepers being unduly strained in the middle. These spike-holes the author considers should certainly not all be placed in the same line, but at opposite corners of the chair.

In the early history of permanent way maintenance, when a road required replacing with new materials or relaying, it was considered necessary to insert cross roads at each end of the piece to come out, and to pilot trains over the single line; these cross roads were placed at intervals of about three-quarters of a mile, and the intermediate space was taken up. But as relaying practice became general, the work was carried on between trains, the connection between the old and new work being made good with a temporary closer. Trains should

be slackened over the road affected night and day, until the new work is permanently made good, each sleeper well packed up and the keys and spikes driven home, as well as the fish plates and bolts made secure.

Relaying may be done to the greatest advantage in early summer or late spring, the road has then an opportunity of taking its bearing before winter.

Relaying is generally done for the following reasons:—

1st and chiefly. To remove from the road worn-out permanent way.

2nd. To supply rails and chairs of particular patterns for repairs; and

3rd. For the supply of a lot of good old rails of the same patterns for repairs, which, owing to the reduction in depth by wear, fish up to the old rather better than new would do.

It will be found on inspecting roads of similar age for relaying, where it is double line on sharp gradients, that the up-hill road will be less worn than the down-hill road, owing to the reduced speed and freedom from oscillation. Under these circumstances, the down-hill road should be relaid first to supply materials for repairs to the up-hill road. Diagrams showing age of road, though valuable as guides, cannot be relied upon to regulate relaying operations, as the life of the rails is much affected by local circumstances, such as drainage of formation, ballast, &c.

In carrying out relaying operations, the new materials, where it is a double line, should be deposited on the outside of the opposite road to that which is to be relaid. The traffic department having been duly advised of the extent and locality of the road which is to be taken out, and the working party and trains protected by signalmen, the ballast should be removed from between the sleepers. After this operation has been carried out to the length which it is anticipated may be safely pulled out between the next two regular trains, the old materials may be removed and the new laid in, and as it is of the utmost importance that this work should be done speedily as well as carefully, each man must know his work, which, for convenience, is generally divided as follows:—

Unscrewing bolts, removing keys, tilting rails out of chairs, and carrying them outside the road that is being relaid. Loosening and removing chairs, and loosening and removing sleepers, levelling ballast for new road, carrying sleepers, regulating distances apart, carrying new rails, to which the chairs may previously have been keyed, linking rails, setting to gauge, boring and spiking joints, and boring and spiking middles.

The ganger should have had a closer cut to fill against the

old work, or he should cut one whilst the work is in operation, if it is a long pull out. As the progress of the work depends upon the activity and training of the men, it is important that they should all know their parts. The author has timed a gang of fifty-five men at relaying work, to ascertain, without their being aware of it, the work they could do in a given time; he found that they relaid eight lengths of 7 yards each in thirty minutes; the first bolt of the old road was drawn at eleven and three-quarter minutes to two, the whole of the men being generally at work at eight minutes to two, and the work finished at twenty minutes past. This is hardly a fair sample of what these men could do if engaged in a quarter of a mile pull out, as no sooner had they got fairly into the work than it was necessary to leave off. Fifty-five men are rather a large gang for relaying operations, especially for a short pull out, as they are too crowded to admit of their strength being fully developed. Forty men and two or three lads will do nearly as much, and from his experience the author considers that they will relay forty 7-yard lengths in two hours; the road, of course, will not all be double spiked, but it will be sufficiently secure for trains to proceed at reduced speeds.

The labour in boring the sleepers takes considerable time in relaying, and the author considers that if care is used to keep the joints opposite, the holes at one end, if not at both ends, might be bored before creosoting. Creosoting the auger holes is worth trying, as it is the part of the sleeper the soundness of which is of greatest importance. The author thinks that if the wood round the spikes is left uncreosoted when the fastening loosens, the wet gets in, and decay supervenes sooner there than elsewhere.

Care should be taken to keep the lifting and packing gangs close up to the relayers, and the opening-out gang not much in advance, to leave as little as possible in length of road weakened by the work at one time; the road should be well boxed up with ballast, and the surface-grips formed as in lifting. In relaying, a space must be left for expansion between the ends of adjoining rails. Of course the amount allowed will depend upon the temperature when the work is done; but as a rule $\frac{1}{8}$ inch between each rail will be found sufficient in a straight road. The labour of ordinary maintenance of permanent way is a considerable item of expenditure. The railway labourer may be described in ability as a half-labourer and half-mechanic. Considerable judgment is required in selecting these men, for, unless the platelayer is up to his work, all calculations of economy will be defeated by a want of skill and judgment on his pa

As regards the staff of men required for the maintenance of permanent way, there are two modes in which it can be managed, either to keep the gangs at the lowest pitch as regards the number of men, taking the month of least work as the standard, and doing all extra jobs by extra men specially engaged, or by contract; or, on the other hand, by keeping a few extra men attached, in the winter months, to the lengths of greatest work, and in summer using them to form the nucleus of relaying, lifting, ballasting, or re-sleepering gangs. The temporary men required to fill up the large gangs will soon become acquainted with their work, and be ready to fill vacancies in the extra gangs, or gangs on the lengths when they occur. Fear might be entertained by economists that this permanent detachment of the extra gangs might either shirk their winter work, or cause the length's men to consider themselves relieved of part of the work in winter, and act accordingly. The author does not apprehend that this would occur, as if a man takes no pride in his work, he will be idle under any circumstances, and the sooner he is got rid of the better.

The number of men in this permanent detachment will, of course, be regulated by the state of the road and weather in each particular winter. The routine of the platelayer's work consists chiefly in packing up low joints or middle sleepers, changing and turning rails, and removing defective rails or sleepers; the ganger's special daily work should be to examine his length from end to end, screw up all fish-bolts, and pack or renew all keys requiring it, and in more extensive repairs he should get round his length as speedily as possible, doing a little in each place, so as to keep it all alike; otherwise it militates against him if he keeps a mile against his house in order, and neglects the other part: the contrast will make the defective portions more apparent.

Interlocking Points and Signals.

Since the year 1856, when Mr. Saxby brought out his patent for interlocking the levers of points and signals, the system has been rapidly gaining ground. It has been introduced voluntarily at existing junctions by proprietors and managers of railways, and has been made a condition of late years by the Board of Trade before the opening of new lines.

The advantages of this system are so apparent and well understood that it is hardly necessary before this Society to enter upon a recapitulation of them. Suffice it to say that by using a properly interlocked lever frame, the points cannot stand contrary to signals given, neither can opposing or conflict-

ing signals be given. Work is concentrated and placed under the care of a man who cannot, because of mechanical difficulties, lower signals haphazard, and who requires, as it were, to be placed in possession of the key to the lever frame, and must know the various combinations before he can work them at all, thus preventing the interference of inexperienced persons.

As regards the mechanical part of interlocking points and signals, various schemes have been invented and applied, some of which have been patented. They may be divided into the following classes:—

1st. Apparatus where the locking is done by slides with notched locks, which secure the levers by direct contact.

2nd. Apparatus where the locks are actuated by rocking shafts.

3rd. Apparatus in which crossing slides are introduced; and

4th. Apparatus invented by Mr. Anderson, with a selecting or king lever.

Various other methods the author has heard of, such as placing one lever before the other, in a frame-slide, to ensure their manipulation in a certain order. But as both point and signal levers, if so placed, could be moved half over, it follows that the points may stand half over and the signal half down, or at caution.

Systems of mechanically incomplete locking are objectionable, being calculated to foster a delusive confidence. Fig. 6 shows a good arrangement of slide locking in one of its applications. The friction is reduced to a minimum in all the working parts, which in locking gear is a great desideratum, as unless this is the case the locks wear and fail to commence the locking as soon as they did before the friction took place. In the figure C C show the levers in their normal position, standing back in the frame. The dotted lines, B C, show the position of the point levers when pulled over, and the dotted lines, A C, show the position of the signal levers when pulled over, *i. e.* when the signal is down. The locking of the signal levers is effected above the floor of signalman's cabin, and that of point levers below, in this arrangement, though not a necessity of this sort of locking, as both point and signal levers can be locked in either position. But an advantage is gained by a combination of the two, as a larger number of slides and locks can be introduced, and a double rank of spindles, E E, D D.

The movement of the point lever from its normal position at C to B actuates, in addition to the point connections, a small horizontal rod, F D, which partly rotates a vertical spindle D D; ar the top of this spindle there is a cam at D, which works a de backwards and forwards at right angles with the plane of

FIG. 6.

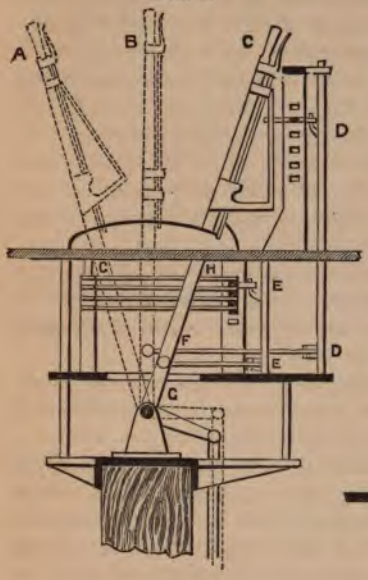


FIG. 7.

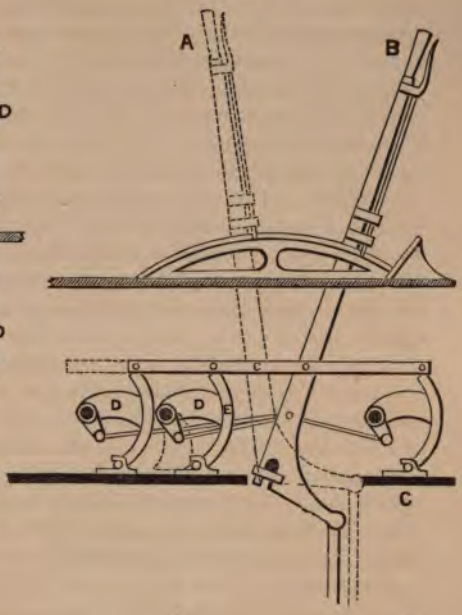


FIG. 9.

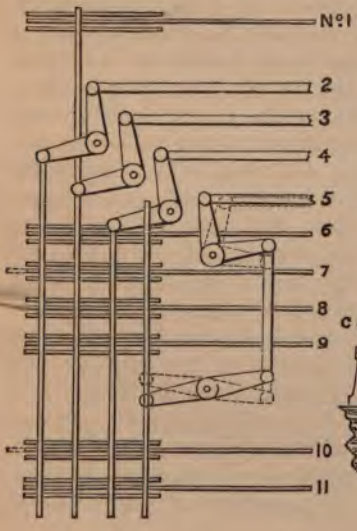
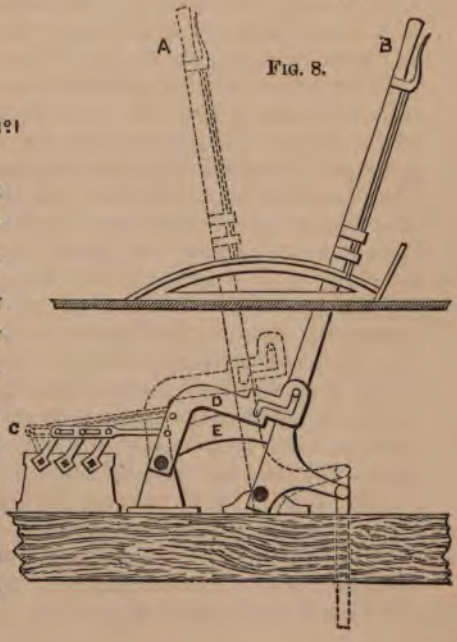


FIG. 8.



movement of the levers. Attached to the slide are hooks which lay hold of or release the proper signal levers to effect any desired combination. The signal levers actuate, when they move the signals, the spindles E E, by means of a short rod, as before described; they lock the point levers with locks G H. These locks work on a vertical spindle at G, as a centre, and they are actuated at the other end by small studs fixed to the slides; the locks catch, release, or back lock the required levers by means of notches at the side. The movement of the spring catch has been utilized to start the locking by connecting a rod worked by it to one of the arms of a small crank, and by attaching the other arm to the horizontal rod which works the vertical spindle before described, the crank being made to move on the same centre as the lever, and closely adjacent.

There have been various applications of the slide movement, more or less perfect, in which the slides have been worked by means of rack and pinion movement, Archimedean screws, slotted locks, as well as locks actuated by side contact with levers, and communicating the movement by means of slides to other locks. The system of locking shown at Fig. 6 is generally used by Messrs. Saxby and Farmer in their apparatus, in all small frames, but at points of convergence of numerous sidings and branches, where seventy or eighty levers are placed in one frame, a compact and ingenious application of the third system by means of crossing slides has been brought out and patented by them.

There are several applications of the system of locking by means of rocking shafts. Fig. 7 shows a very neat and effective application of that system, the invention of Mr. Francis Brady, principal Resident Engineer of the South-Eastern Railway. The two positions of the levers and locks are shown in the figure in strong and dotted lines. The movement of the point levers from B to A, besides working the point connections, actuates a small rod as in the spindle locking. This rod works on a cam, and partly rotates a horizontal rocking shaft; this, in its turn, gives movement to the locks D; these locks secure or release the curved links E, according to the position of the point lever. When the point lever is over in position A they lower the lock, which allows corresponding signals to be pulled over, the connection being formed between the signal lever and link by the horizontal bar C. When the signal levers are over to the position shown at A, a secure back lock is given to the points, the curve of the two faces of the lock and the inside of the curved link being to the same radius. There are many advantages to recommend this arrangement, among which may be mentioned facility for inspection, interchange of parts, ready

enlargement and simplicity of construction, as well as total absence from friction in the locks themselves. At the Redhill Junction, one of the places inspected by the author where this system is applied, there are two branch-line junctions in addition to station-platform siding-points and engine-shed roads, which, with their respective signals, are all interlocked and under the control of the pointsman. This junction-box contains thirty-one levers. Mr. Brady's system has also been successfully applied at Reading, St. Leonards, Surrey Canal, Waterloo Junction, and other places, in addition to which a point box at the London Terminus has been fitted up, this system being there applied with the locks and gearing working vertically.

Messrs. Mackenzie, Clunes, and Holland, of Worcester, have patented an arrangement of locking by means of rocking shafts, which is shown at Fig. 8. This method differs from the last named in that the levers are locked by means of slots or arms, working against studs projecting from the lever sides. The movement of the point lever from the position shown at B, in addition to working the point-rod connections, works the slotted links, D, to a new position shown in dotted lines. This in its turn actuates a rod, which partly rotates a rocking shaft at C. This rocking shaft in its two positions opens and closes the lock E, and, by means of slotted bars, releases or locks corresponding or conflicting signals or points, and back locks the point levers at A if required.

Figure 9 shows a system of locking brought out by one of the *employés* of the North Staffordshire Railway Company some years since, and used with great success at important junctions, and in extensive combinations in goods yards on that line of railway. All the gearing is very strong, and the locking is accomplished by the simplest mechanical contrivances. The drawing is a copy of the locking in operation at Stone Junction, which the author had an opportunity of inspecting through the kindness of one of the Directors. Rods 2, 3, 4, and 5 are attached to four sets of point levers, which work the junction points, a cross-over road, and points leading out of a siding.

Bars 1, 10, 11, are attached to distant signal levers, and 6, 7, 8, 9, are connected to the junction semaphore levers; the locking is effected by means of other wrought-iron bars crossing these bars at right angles and notched half through or plain, to lie on or through the flat bars, attached to the signal levers, as required in the combinations of the locking. These cross-bars are actuated by means of cranks, attached to point-lever rods Nos. 2, 3, 4, 5. No. 5 rod is attached to trailing points lever, which, on being worked, actuates the top crossing slide to the left, shown in dotted lines, and brings a notch opposite to lever bars 7 and 10,

which permits a movement to be made and the signals lowered. The movement of bar No. 10 to the position shown in dotted lines brings a plain part of it opposite the notches in bars working from conflicting signal and point levers, thus ensuring a complete, effective, and simple lock.

The author has not had an opportunity of inspecting Mr. Anderson's apparatus for accomplishing the locking of points and signal levers, but he understands that its characteristic feature consists in a selecting or king lever placed in the centre of the frame. This lever actuates a perforated selecting plate, which is placed directly opposite, into as many positions for point levers to work as there are combinations in the frame. These point and signal levers are permitted to move or otherwise, only when there is a hole in the selecting plate opposite and corresponding in shape to the rod which is attached to each lever. Some of these rods are tapered at the end, so as to alter the position of the selecting bar and render the movement of the bars attached to the other levers possible. They also lock the bars by forcing the edges of a hole in the selecting plate into notches on the sides of the bars attached to opposing signals or points. The replacement of levers in the frame can only be done in reverse order.

Some of the requisites in a good locking apparatus are certainly of working strength, completeness of lock and facility for repairs and inspection. It should not be possible for the pointsman to commence the movement of corresponding signal levers without having first completed the movement of his point levers, and the strength of the apparatus should be such as to give confidence in the certainty of its working.

Various contrivances have been brought out to take up the slack wire of distant signals, and to keep it taut during sudden changes of temperature, but the author has not yet seen one that would act without occasional rectification. He thinks that the wire of distant signals might be traversed in the pointsman's cabin, so that the man in charge might occasionally regulate it with a screw coupling without the necessity for leaving his cabin and stepping outside.

In conclusion, the author need only say that he has endeavoured to place before this Society a few facts having reference to Railway Maintenance as they have been brought under his notice during an experience of twelve years. The subject needs no apology, for whether we consider our railway system in its monetary aspects, affecting directly or indirectly, by its prosperity or otherwise, the incomes of thousands of shareholders, in its mechanical requirements, which employ the constructive abilities of our profession to a very large extent, or in its social

and political relationships affecting the comfort, convenience, and prosperity of States, there is no question of an engineering character of greater importance than the safe and economical maintenance of our railway communication.

APPENDIX.—TABLE A.

COMPARATIVE WEAR of STEEL and IRON RAILS under SIMILAR TRAFFIC.

Steel Rails.			Iron Rails.		
Time under Traffic.	Length.	Failures per cent.	Time under Traffic.	Length.	Failures per cent.
2 years	1 mile	Nil.	2 years	1 mile	·76 per cent.
3 yrs. 4 mths.	0 m. 762 yds.	"	3 yrs. 4 mths.	1 "	1·72 "
5 yrs. 2 mths.	0 m. 800 yds.	"	5 yrs. 2 mths.	1 "	5·14 "

NOTE.—The rails are all double faced. The percentages of failures refer only to first face of iron rails.

APPENDIX.—TABLE B.

SUMMARY of OBSERVATIONS taken during 18 MONTHS, to ascertain the LIFE of REVERSIBLE CHAIR-INDENTED IRON RAILS. OBSERVATIONS taken on 335 RAILS. BALLAST, GRAVEL, or ASHES.

Life of First Face of Rails given in Years.	State of 2nd Rail Face when observations were taken. Time in use given in Months.													Totals.		
	4 Months.	5 Months.	6 Months.	7 Months.	8 Months.	9 Months.	10 Months.	11 Months.	12 Months.	13 Months.	14 Months.	15 Months.	16 Months.			
	U. C. W.	U. C. W.	U. C. W.	U. C. W.	U. C. W.	U. C. W.	U. C. W.	U. C. W.	U. C. W.	U. C. W.	U. C. W.	U. C. W.	U. C. W.	U.	C.	W.
2 years ..	..	..	..	..	..	..	..	..	..	..	5 2 0	..	..	5	2	0
6 „ ..	0 0 1	..	..	..	..	..	..	0 0 1	6 1 0	23 4 2	..	..	..	29	5	4
7 „ ..	..	..	..	..	..	..	0 0 1	0 0 1	3 1 2	1 2 4	12 5 1	3 2 1	0 2 4	19	12	14
8 „ ..	..	0 0 1	..	..	..	..	..	..	3 0 0	21 3 0	..	..	..	24	3	1
9 „ ..	0 0 1	..	0 0 1	0 0 1	0 0 1	0 0 1	..	7 2 0	24 3 3	10 9 0	10 8 0	11 8 1	3 0 0	65	30	9
10 „ ..	..	..	0 0 2	..	..	..	..	..	6 6 0	7 9 0	1 1 1	..	..	14	16	3
11 „ ..	..	..	..	..	..	..	..	..	7 3 0	11 0 1	0 2 0	..	..	18	5	1
12 „ ..	0 0 1	..	..	..	0 0 1	..	..	..	0 1 0	17 12 0	5 5 1	2 2 0	..	24	20	3
13 „ ..	..	0 0 6	..	0 0 1	0 0 2	..	..	..	..	..	..	..	..	0	0	9
														198	93	44
													Total ..	335		

NOTE.—The Columns headed U. C. W. show the number of Rails Uncrushed, Crushed, and Worn out, when the observations were taken.

December 5th, 1870.

WILLIAM ADAMS, PRESIDENT, IN THE CHAIR.

THE ECONOMICS OF RAILWAY MAINTENANCE.

DISCUSSION.

MR. GRIFFIN introduced in connection with the subject of the paper a new form of permanent way which possessed a marked feature of economy, and which had been worked out by him. Specimens of the rails and sleepers were placed before

FIG. 10.

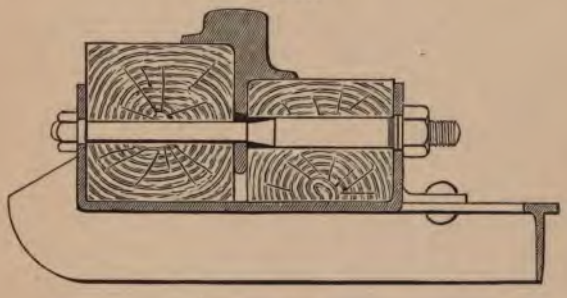


FIG. 11.

the meeting, and they are illustrated in Figs. 10 and 11. Mr. Griffin explained the system, and observed that the object in completely altering the form of the rail was to get by its position

and depth greater vertical strength. The rail was six inches deep, and there was 100 per cent. more work to be got out of his section than out of either the double-headed or the Vignoles section. Mr. Barlow had stated that from the double-headed and Vignoles 82-lb. rails less than a quarter of an inch of wear was obtained. His (Mr. Griffin's) was only a 60-lb. rail, and was superior to the other forms because there was the utmost amount of wearing surface in the head, besides which its form gave the full vertical strength. He used less than half the quantity of timber required in the old system, and that timber could be bought at half the ordinary price, because instead of being restricted to sleepers of 9 ft. × 10 in. × 5 in. he used sleepers 2 or 3 ft. long, and 5 or 6 in. scantling, so that there was scarcely any waste. It was from 300*l.* or 400*l.* per mile cheaper than the ordinary chair system, and presented unusual features of economy. The joint was made by passing an iron plate completely round the rail, and it was held in place by two bolts, which were eccentric bolts or bolts made with two different diameters, and as the bolts were drawn through they tightened the rails upon and powerfully compressed the timber, making a very good joint. All the fastenings locked themselves. The hole in the jaw or angle plate was punched with a slight flattening in the top, and the collar of the nut was also flattened at top and bottom, so that every half turn brought the two flat surfaces together, so that they could never work out of place. When the fastening was once screwed up tightly, it scarcely required any adjustment at all. Another feature in the arrangement was good drainage. The author of the paper had observed that one of the great things they had to consider in permanent way was good drainage. Every one of the pieces of T iron which kept the line in gauge formed a drain of itself, and instead of the timber lying soaking in the wet the water was carried off by the indentation made in the ballast by the iron used for foundations. Old rails might be used for the foundations, and the object in that was that instead of paying 10*l.* or 11*l.* per ton for T iron or other similar iron, in some countries—Spain, for instance—old rails could be had for 2*l.* 10*s.* or 3*l.* per ton. That would enable engineers to get three or four times the weight of old worn-out rails, and thus a much more substantial foundation, for the same price. The quantity and cost of timber required for making a road was very small with the iron foundation. The old sandwich system of Mr. Bridges Adams for the first few years of its use proved to be an admirable system, and he (Mr. Griffin) believed that all engineers agreed that it was one of the best for the even wearing of the rails, and also for the rolling stock. But it

subsequently failed, and the reason of its failure, as stated by Mr. Adams, was that he was obliged to have mathematical accuracy in every part, because if there was the least play in any part it rapidly became worse. Mr. Adams also found that the long timbers which he was obliged to use, after some years twisted and warped and shifted out of place, and it was almost impossible to get the holes in the timber directly opposite the holes in the rail itself. He (Mr. Griffin) preferred the bridge rail, because in it the lamination was very much less than in either the double-headed or the Vignoles rails. The reason was that the head of either the Vignoles or double-headed rail gave way for want of support underneath the inner side of the head, whilst the bridge rail gave way in the crown of the arch, and it thus laminated out both sides. When the double-headed rail gave way it cut the tyres of the wheels and laminated out to a much greater extent inside the rail, whereas in the bridge rail nearly all the lamination, except where it split the crown longitudinally, or was occasioned by a defect in the metal, went away from the tyre of the wheel. The great fault of the bridge rail was that it had not sufficient vertical stiffness, and the greater the pressure put on it the more it tended to open, damage the timber, and displace the fastenings. On curves and at high speeds the pressure was thrown much more on one side of the bridge rail than the other, and the consequence was that there was a tendency to press and tilt the rail, and which was always increasing. If a solid head was used a much better effect would follow as far as lamination went, but then it would not have adequate vertical stiffness.

Mr. Burnett said that the author of the paper had stated the lengths of the rails upon the Metropolitan District Railway to be 18 ft., but 24 ft. was the standard length. There were a number of rails in 18-ft. lengths, because it was necessary on curves and for the making up of lengths to have shorter rails, but the standard length was 24 ft. There was also an intermediate or 21-ft. length, which was used in laying the line, as well as another of 15 ft., the proportions of the various lengths used being:—

About 50	per cent of	24	feet.	
25	„	21	„	
15	„	18	„	
And 10	„	15	„	which was used to make up lengths.

Mr. Nursey said that with regard to the relaying of the rails, he thought the author of the paper employed a greater number of men and made a longer process of it than was necessary. On

the Blackwall Railway, where the traffic was very quick during the day, it was the custom to have the rails already keyed into the chairs and the sleepers ready bored, the work being done in the shops; so that a given length of line was relaid in a very short time during the intervals of night traffic. That appeared a much quicker process than that described by the author. With regard to the general subject of the economics of railway maintenance, the question was a very wide one, and it appeared to him (Mr. Nursey) that the real economy of railway maintenance would be found to consist in reducing the gauge and the weight of rolling stock upon such lines as were yet to be constructed. It would not be possible perhaps to introduce such a system on existing railways, although on the Great Western Railway the 7-ft. gauge was gradually being replaced by the narrow gauge; and wherever opportunity occurred, and as the broad-gauge rolling stock was worked out, this reduced gauge of 4 ft. 8½ in. was introduced. Why therefore should not a still narrower gauge be used for future lines—especially those destined to act as branches or feeders to main lines? It was not a new question, for it had been mooted before; but it was an important one, and within the last few months it had taken a very practical turn. In his report on the Indian railways Mr. Fowler had arrived at the conclusion that a 3 ft. 6 in. gauge should be adopted, and the reports of other engineers appointed to examine into the question, and who did not agree with Mr. Fowler, recommended a 2 ft. 9 in., which was exactly half the present Indian gauge. Mr. Fairlie had made some very practical remarks upon the subject of light railways and their equipment in a paper which he had recently read before the British Association. In the first place he started with the proportion of paying to non-paying passenger trains as being as much as twenty-nine to one; and in goods trains, exclusive of minerals, as much as seven to one. Mr. Fairlie then went on to say that the terrible disproportion was partly due to the system of management pursued; but in a far greater degree to the gauge. The dead weight of trains conveying either passengers or goods was in direct proportion to the gauge on which they ran; or, in other words, the proportion of non-paying to paying weight (as far as that was independent of management) was increased exactly as the rails were farther apart, because a ton of materials disposed upon a narrow gauge was stronger as regarded its carrying power than the same weight when spread out over a wider basis. In proof of that proposition Mr. Fairlie cited the case of the Festiniog Railway, with its gauge of 1 ft. 11½ inches. The wagons [illegible] upon it for carrying timber weighed only 12 cwt., and [illegible] uently carried a load of over 3½ tons at a speed

of 12 miles an hour. In other words, those wagons carried as much as six times their own weight, whilst the best wagons on the ordinary English narrow-gauge lines did not carry as much as twice their own weight. Mr. Fairlie then dealt with the traffic of the North-Western Railway, and worked out as a result that a 3-ft. gauge line could carry without an additional shilling for haulage 2½ times as many tons as were then carried over the 4 ft. 8½ inch gauge of the North-Western Railway. He (Mr. Nursey) therefore held that the reduction of the gauge and weight of the rolling stock were points to which the most careful attention should be given in the construction of future railways. The necessity for cheap light lines appeared to him (Mr. Nursey) to be evidenced by the manner in which the daily mail service of the country was performed; very little more than half that service was done by rail. The rail mileage was 45,000 miles, and that of omnibusses or other mail conveyances was 39,000 miles, showing that there was a very wide field for enterprise in the direction he had indicated, provided the construction could be brought down to economical terms. A railway constructed on the narrow gauge, and with stock such as Mr. Fairlie proposed, and a permanent way such as Mr. Griffin proposed, would be productive of very great economy in maintenance.

Mr. Crompton, in reply, said that Mr. Griffin's observations respecting the double-headed rail were not quite correct. He (Mr. Crompton) had had considerable experience with that rail, and he found that it crushed on both sides without distinction, but the outside laminations were not dangerous because they did not rest on the rail, whilst the inside laminations were dangerous because they interfered with the flanges of the wheels. It was only when the rails were crushed on the inside that they had to be removed. The outside laminations were objectionable because the rail would not fit the chair when turned. With regard to the remark made by Mr. Burnett respecting the lengths of the rails on the Metropolitan District line, what he (Mr. Crompton) had stated was taken from an article in *Engineering*, in which the length was stated to be 18 ft.; of course 24-ft. lengths would be better. With regard to the question raised by Mr. Nursey as to the work done by platelayers, he thought it was good work for 55 men in half an hour to remove 16 chairs, with the rails, and lay 56 new sleepers in position, regulate the distances, bore 200 holes, and drive in as many spikes afterwards; and in addition to that, to remove 16 old rails, with their chairs and sleepers, and carry them across the other road. He had superintended that work and knew that it was properly performed.

Of course, relaying could be done in the night, when there was no interference from trains, with much greater facility than in the day, as the passage of trains was a great hindrance in relaying.

The PRESIDENT said that the subject of permanent way was a most important one, and there was such varied practice with permanent way engineers as to render it very desirable that there should be some standard to which all should work. On some lines rails were keyed on the outside, and on others they were keyed on the inside, and there was a division of opinion as to which was the better plan. Then the joints were matters that gave a great deal of trouble, and, as yet, there was no really satisfactory plan for supporting the joint introduced into general practice. Then, again, from the facts which the author of the paper had brought before the members it did not seem as if engineers could get a due proportion between the life of the chair upon the sleeper and that of the sleeper upon the ballast. They ought to be duly proportioned, and that opened a field of inquiry and research. There were many points in connection with permanent way respecting which no satisfactory conclusions had been arrived at. There was the question of the preference of single or double-headed rails, and the longitudinal or transverse system of roads. All those were matters which required investigation, and it would be well for the profession if all such questions could be satisfactorily settled. Mr. Crompton's paper tended greatly to the advancement of that subject, and would prove of value to railway engineers.

THE END.

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